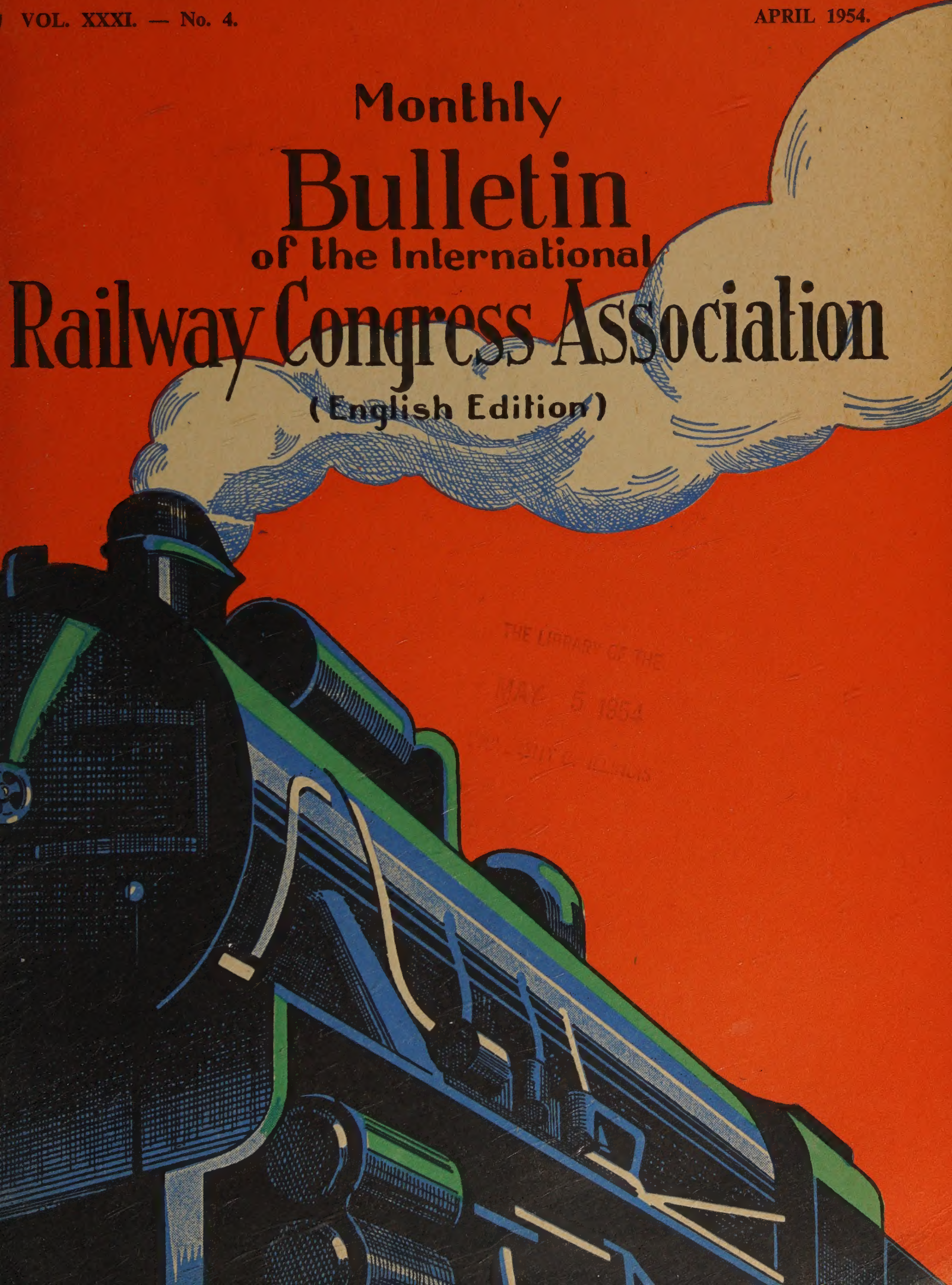
VOL. XXXI. — No. 4. APRIL 1954.

Monthly
Bulletin
# of the International
Railway Congress Association
(English Edition)



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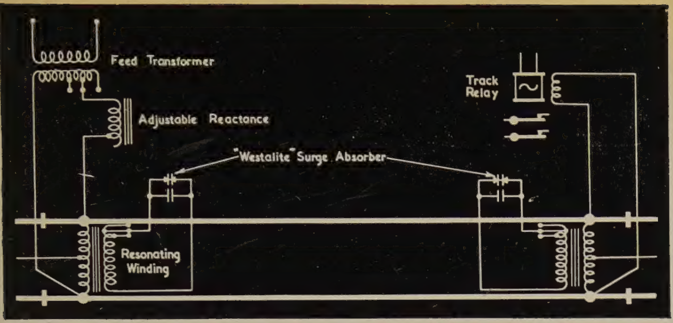

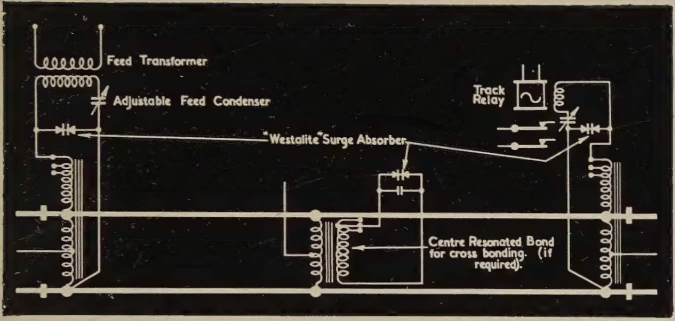
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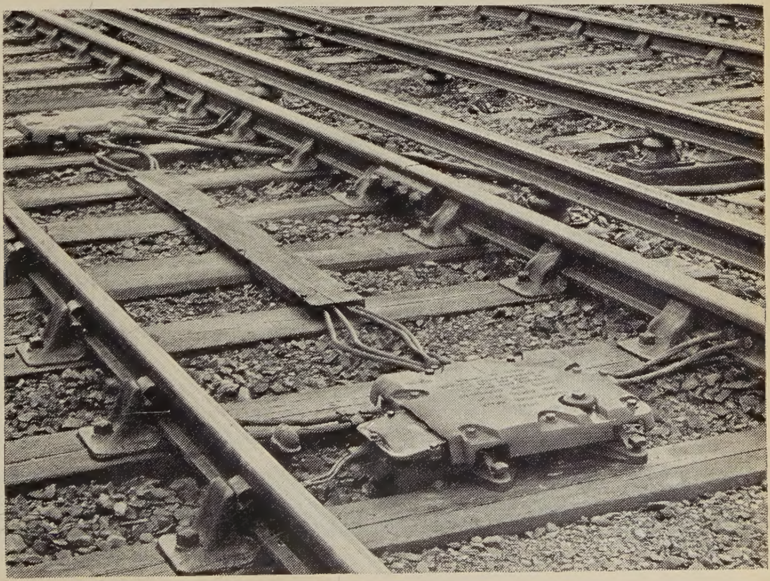

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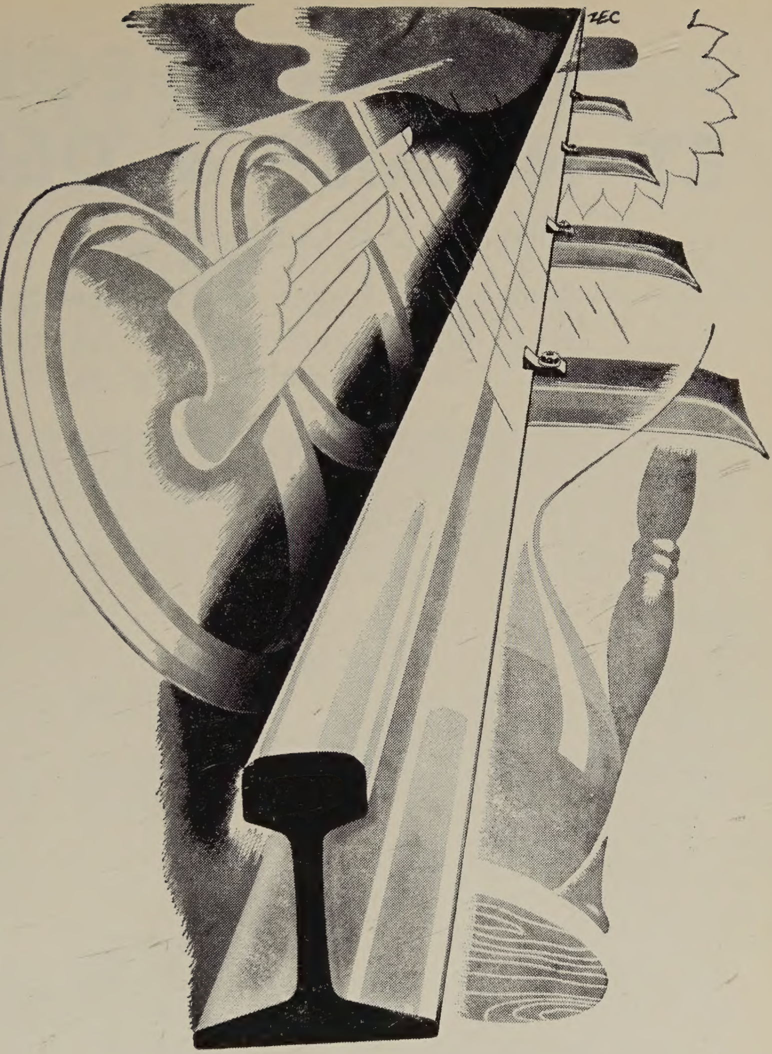

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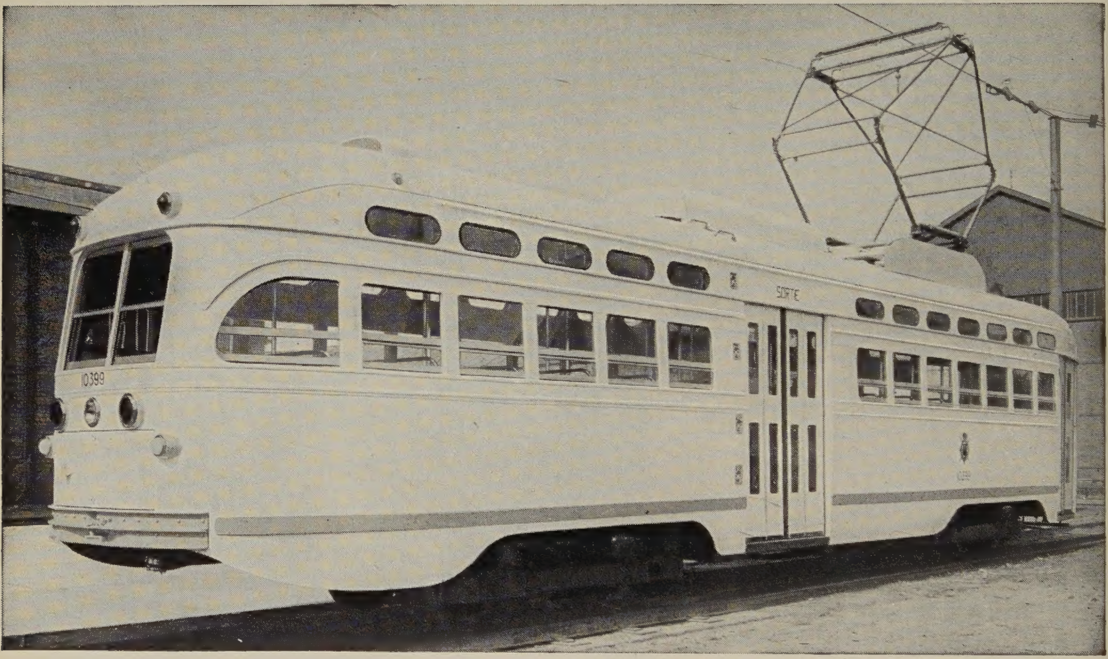

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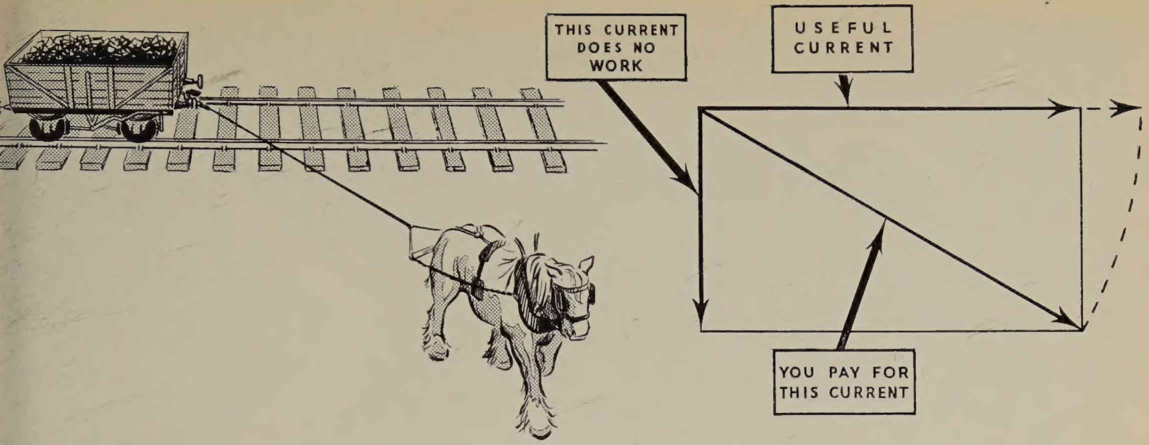

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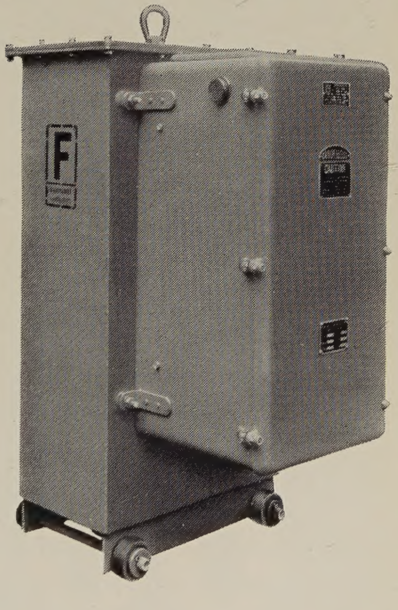

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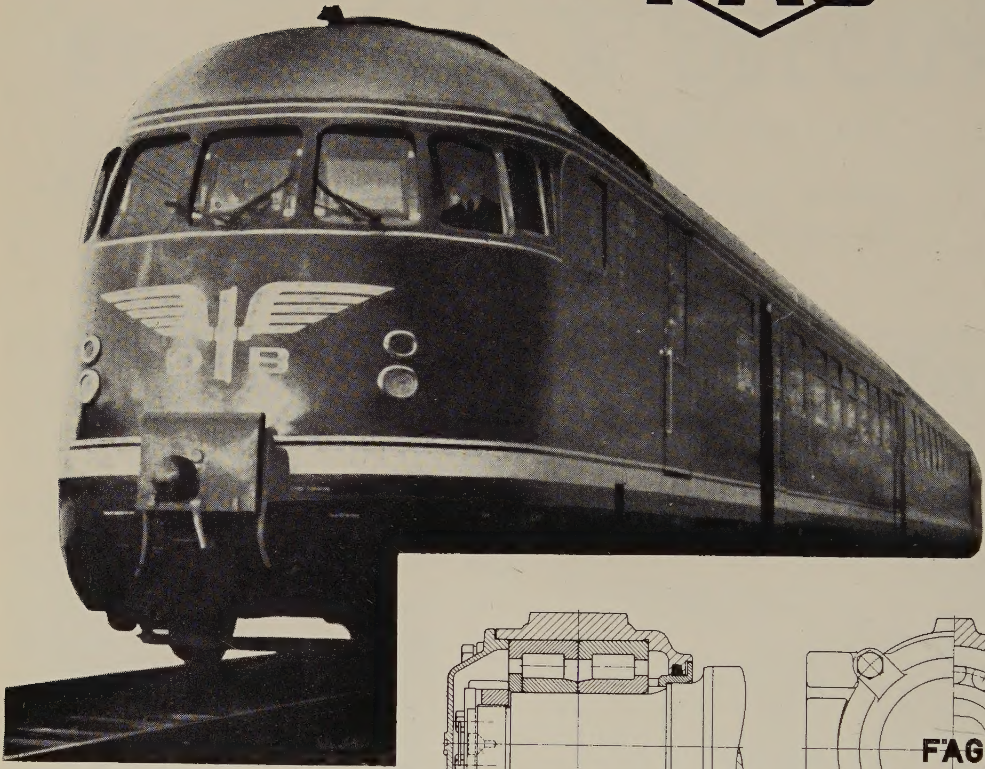

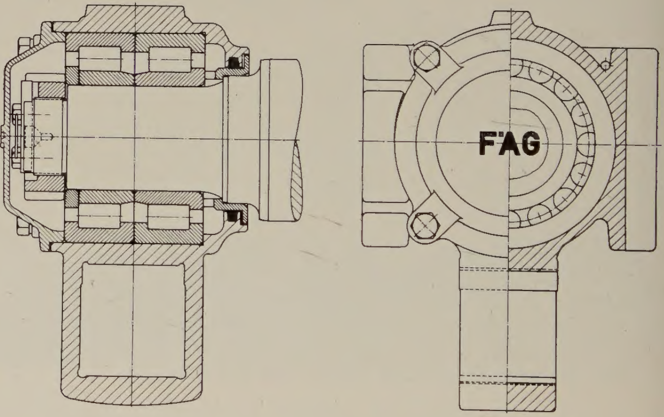

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MONTHLY BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS ASSOCIATION
(ENGLISH EDITION)

PUBLISHING and EDITORIAL OFFICES : 19, RUE DU BEAU-SITE, BRUSSELS

Yearly subscription for 1954 :
Belgium . . . . 700 Belgian Francs
Universal Postal Union. . . 800 Belgian Francs

Price of this single copy : 100 Belgian Francs (not including postage).

Subscriptions and orders for single copies (January 1931 and later editions) to be addressed to the General Secretary, International Railway Congress Association, 19, rue du Beau-Site, Brussels (Belgium).

Orders for copies previous to January 1931 should be addressed to Messrs. Weissenbruch & Co. Ltd., Printers, 49, rue du Poinçon, Brussels.

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An edition in French is also published.

Vol. XXXI. — No. 4. April 1954.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[656 .254]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

16th. SESSION (LONDON, 1954).

QUESTION 5.

Radiophonic communications in railway working.

REPORT

(Austria, Belgium and Colony, Bulgaria, Czechoslovakia, France and French Union, Germany, Greece, Hungary, Italy, Luxemburg, Netherlands, Poland, Portugal and Colonies, Rumania, Spain, Switzerland, Syria, Turkey and Yugoslavia),

by Dipl. Ing. J. Frischauf,
Referent für Fernmeldewesen in der Generaldirektion der Österreichischen Bundesbahnen.

The following Administrations replied to the questionnaire for Question 5 :

1. Deutsche Bundesbahn.
2. Austrian Federal Railways.
3. Belgian National Railways Company.
* 4. National Light Railways Company.
* 5. Compagnie belge de Chemins de fer et d'Entreprises.
6. OTRACO.
7. R.E.N.F.E. (Spanish National Railways).
8. Société Nationale des Chemins de fer Français (S.N.C.F.).
* 9. French Light Railways Company.
* 10. Régie Autonome des Transports Parisiens (R.A.T.P.).
* 11. Compagnie Générale de Voies Ferrées d'intérêt local.
12. Algerian Railways.
* 13. Gafsa Railway.
* 14. Tunisian Railways.
* 15. French Equatorial African and Cameroons Railways.
* 16. French West African and Togo Railways.
* 17. Franco-Ethiopian Railway from Djibouti to Addis-Ababa.
18. Moroccan Railways.
19. Mediterranean-Niger Railway.
* 20. Greek State Railways.
* 21. Pireus-Athens-Peloponesian Railways.
22. Italian State Railways (Rome).
* 23. North of Milan Railways.
* 24. Milan Municipal Tramways Company.
* 25. Luxemburg National Railways Company.
26. Netherlands Railways.
27. Portuguese Railways Company.
28. Swiss Federal Railways.
* 29. Rhaetian Railway.
* 30. Viege-Zermatt Railway.
* 31. Syrian State Railways - Northern line.
* 32. Czechoslovakian State Railways (Prague).
* 33. Turkish State Railways and Harbours.
* 34. Chemins de fer non Concédés du Viet-Nam.
35. Cambodian Royal Railways.

The Administrations indicated by an asterisk have no radio-telephonic installations and have made no trials with such.

* * *

The particulars given in this report are based on the replies received from the Administrations listed above.

The report has been drawn up following the arrangement of the questions in order to facilitate the task of the special reporter when inserting the replies coming from the English speaking countries.

In the first part, which refers principally to questions of a general character, technical terms have been used only as far as was indispensable to an understanding of the text.

The second part deals entirely with technical matters.

PART I.

QUESTION 1. — *Have you any installations utilising radiophonic communications in railway working? If so, please state in general terms the extent and nature of such installations, whether in regular use or for emergency purposes only, dealing with more detailed aspects under the specific questions which follow.*

Is the operation of the wireless service governed by rules and instructions covering :—

a) *actual operating and traffic;*

b) *maintenance of the wireless installations?*

If so, please enclose the Rules and Instructions in question.

The use made of radio-telephony by the various Administrations or the trials carried out by them with that object, cover the following applications to traffic working, viz :

a) Use of radio in marshalling yards for effecting communication between fixed points, generally the one from which the marshalling is regulated, and certain moveable ones, formed by the locomotives engaged in the shunting operations.

Installations of this kind are widely used by certain managements, especially at the heavily worked yards where they are moreover in continuous operation. The S.N.C.F. points out that the oldest of such installations were put into service in 1947 and the most recent in 1952, 17 yards having been equipped up to the present. This is the largest number of installations being operated by one management.

b) In connection with the *marking of wagons* prior to sorting, both the German Federal Railways and the S.N.C.F. have already obtained good results from radio links between the man doing the marking and the hump cabin of other fixed point. The German Railways, in addition, contemplate giving in the near future portable equipment to the yard supervisor's staff, to those engaged in marking up the trains and to the wagon examiners.

c) In *maintenance work,* more particularly for effecting communication between a gang out on the line and some fixed point — signal box, etc. — the gangers having portable apparatus and the fixed locations either portable or fixed, as the case may be.

d) The German Federal Railways (D.B.) also report the use of portable equipment in connection with *banking and assisting engines,* communication being established in each case between such engines and certain fixed points along the route. The Austrian Federal Railways (Ö.B.B.) have made trials of means of communication between the engine at the head and the one at the tail of a train, again using portable apparatus.

e) Certain Administrations which operate *ferry* and *river boat services* have applied radio-telephony between points on shore or the river banks and these vessels.

f) Some managements such as the Italian State (F.S.), German Federal (D.B.) and the Spanish Railways, have established radio communications between certain fixed points, some installations being already in service and others on trial. The F.S. in particular have organised special radio links such as for example a *district group* or network connecting 14 important points in the country with the general offices in Rome, and another group comprising 9 *electric traction supply* points. There is a third one with 4 stations in Sicily, one in Sardinia with 3, another with 5 in Calabria with, in addition, a *radio link* across the Straits of Messina.

The Swiss Federal Railways (C.F.F.) have applied portable radio installations at Erstfeld station for *regulating the movement of the trains* and *supervising brake testing*. In the case of very long freight trains, it is impossible to see from one end to the other at this station and the ordinary means of communication are most unsatisfactory. Radio links allow of direct conversation between the driver and the staff moving about beside the trains and carrying out the inspection work, etc.

The Cambodian railway system states that it has set up radio links in replacement of wired communication, seeing that in consequence of the *political situation* obtaining there the wire lines are frequently cut and rendered useless.

Except in the case of the C.F.F., the managements usually apply as operating and maintenance regulations the instructions issued by the suppliers of the apparatus. This appears to be due in part to the fact that these installations have been in use for a relatively short working period on the railway, as well as to the considerable number of designs in use.

QUESTION 2. — *In the event of your not having any such installations, have you at any time conducted experiments with radiophonic communication, and with what results?*

Please also give replies to any of the following questions which are relevant.

Some of the managements state that they are conducting trials with the idea of applying radio to *other branches of railway operation*. The D.B. is at present carrying out trials with *radio links between trains in motion, public broadcasting service with the trains, connection between the front and rear of a train*, and the *remote control of vehicles*.

The S.N.C.B. reports trials to establish communication between trains in motion and the public telephone system, but these were given up as it was found such arrangements could not be made to pay on the Belgian lines. This will be referred to in more detail when dealing with Question 27.

Trials for the purpose of establishing connection *between the front and rear of a train* appear, from the information received, not to have led to any result. The Algerian Railways state that such experiments have failed hitherto on account of the tunnels on the section where they were made.

The Spanish Railways report that the trials made up to the present have given good results.

The Moroccan lines have at present only one *experimental radio-telephonic installation* comprising 4 fixed points, the maximum distance covered being 18 km (11 miles). To improve wagon user, this Administration has installed a radio coach, allowing of contact being kept up between the industrial district and the station in Casablanca.

The Netherlands Railways have carried out some trials in association with the Netherlands Post Office to ascertain the possibility of using radio links between *some fixed points and trains in motion*. These trials effected at a frequency of 150 MHz have been satisfactory.

The Portuguese Railways have established radio links only to replace existing communications destroyed by cyclones and these are the only experiments they have made with such apparatus.

The Cambodian Railways state that their organised radio links serve more often for telegraphic communication and only in a secondary degree for telephonic.

Generally speaking, all managements which have replied are greatly interested in this subject, hoping to obtain some economic gain from the introduction of radio communication.

QUESTION 3. — *Do you employ radiophonic communication :—*

a) *between the members of a train crew;*

b) *between trains and fixed points;*

c) *between moving trains;*

d) *between main centres and wayside points;*

e) *in marshalling yards;*

f) *for number taking or train examination, etc. by means of portable « walkie-talkie » apparatus;*

g) *for engineering operations.*

Where applicable, please describe the systems, the objectives, and between what offices or individuals the communication takes place : for example, in marshalling yards is it between supervisors and shunting staff, or signalmen, or locomotive crews?

a) *Communication between the Staff on a train.*

The Austrian Federal Railways (Ö.B.B.) report trials with portable apparatus for communicating between the front and rear of a train. It was a question of establishing it between the train engine and the assisting engine, or between the guard at the rear and the driver. Tests took place on a heavy incline on which there were tunnels. The equipment had a power of 0.4 W and worked either in the 4 metre or 2 metre wave band. It was arranged to give bothways communication with Calling by voice. Each post or set of equipment, was arranged to be normally ready to receive and had hand microphones with a switch button in the handset which when pressed put the apparatus in condition to transmit. The maximum distance between two posts was 500 m (546 yards). Verbal communication was in some places of medium quality, even within sighting distance. In a tunnel, it was possible to keep up communication only over a short distance. So far the trials have been effected only from the point of view of obtaining quality of transmission and not strength or amount, so that measurements to arrive at the intensity remain to be made.

In addition, mention may be made of the trials referred to above, carried out by the Algerian Railways. The S.N.C.B. has also studied this question very fully and reference will be made to it again in dealing with the conditions of transmission in tunnels.

b) *Communication between trains and fixed points on the line.*

As regards this matter, the D.B. reports using the method mentioned already in connection with Question 2, communication between the assisting engine and the traffic operating centres, along the railway.

The Mediterranean-Niger Railway uses radio links between trains and railcars on the one hand and fixed points on the other on the Colomb-Bechar-Abadla and Oujda-Colomb-Bechar lines. The fixed equipment is located at Colomb-Bechar and the movable sets are installed in the guards compartments in the trains. Communication can be established either between the fixed points and the movable apparatus or between two of the latter.

The Italian lines (F.S.) have for some years been making trials with communication between trains and fixed points, either in the form of radio-telephonic links or of high frequency communication by carrier current. Detailed particulars of these trials have been given in the technical press. The Cambodian Railways have radio links of this kind; they serve principally to enable the military authorities to maintain safe working of the trains, but are also used to give working instructions to the staff on a train.

c) *Communication between trains in motion.*

What has been said under *b*) concerning the Mediterranean-Niger Railway applies here; as stated, so far it is merely a matter of experiments.

d) *Communication between fixed points.*

This is used by certain Administrations to increase the existing general communication network without having to construct aerial lines or lay down cables, or to establish communication where the existing wire system has been destroyed by atmospheric disturbances or acts of war.

According to details supplied, the German Railways have put into service in 1952 a radio network comprising 16 actual links between Munich and Nuremberg. Communication is established by selection and the system has hitherto given no cause for complaint.

The R.E.N.F.E. contemplates setting up radio-telephonic links especially to meet service operating conditions. It is proposed to divide the territory into 7 zones, each comprising a certain number of radio equipment. Each of these zones will have in addition to a central post within its own boundaries, another in Madrid itself. The posts in any one zone including the one in Madrid, operate on a pair of pre-determined frequencies. The frequencies (pairs) of the various zones are different. In the interior of each zone only one communication, or transmission of a message can proceed at one time, and during that interval, the others receive an indication of « occupied » and are themselves prevented from operating with the exception of the central post and the one in Madrid. This central post can break into and interrupt a communication at will. It can then in addition set up another if it wishes (priority). The Madrid post also can intervene in its own zone and beyond it in the others (super-priority). Special frequencies are used to obtain these priorities. Connection between the posts in the different zones are made by the one in Madrid. Communication can likewise be established equally between this network and the remainder of the railway system.

The F.S. have a radio-telephone network mentioned above, when dealing with point 1. This serves to connect the district network with those of Calabria, Sicily and Sardinia, and the connection across the Straits of Messina.

e) *Radio-telephony in marshalling yards.*

This is the widest use yet made of radio-telephony. Generally speaking, in this case radio links are used between some fixed point and locomotives in the yard, but on the other hand replies received do not allow of determining whether it is intended to give shunting staff portable equipment, or whether trials have been made. The type of installation differs between one railway and another. Nevertheless, a general tendency is to be observed from the engineering point of view. All the equipment must, of course, be adapted to the difficulties met with in railway working. It must at least be weathertight and, if need be, well arranged to disperse any heat that may be generated by it. As to the type of modulation the most usual method is to modulate the frequency. The S.N.C.B. uses also radio equipment having amplitude modulation. All types work within wave bands of *4 or 2 metres.*

In large installations, the selective system of calling is used. Reception takes place in the majority of cases via a loud speaker, and in certain exceptional cases over an ordinary hand receiver set.

f) *Radio-telephony with portable apparatus for noting the marking of wagons prior to sorting, for the examination of trains, etc.*

In addition to the the D.B., of which mention was made above, the S.N.C.F. also uses radio links for this purpose. The man doing the marking of the wagons has portable equipment by which he can keep in constant touch with the hump cabin, working on the duplex system with amplitude modulation. The transmitting power of the fixed apparatus is of the order of 20 W, and of the portable one, 0.3 W. The fixed apparatus allows of 6 frequencies being used and the portable 2; of these one only serves for transmission and this is special to the particular apparatus in question, the second frequency being common to all portable equipments and serving for reception. The fixed post calls the others by speaking on the general frequency and the one being called replies on its own. The messages from the man doing the wagon marking, as he passes round the sidings, are recorded on the ribbon of a magnetophone, which functions only when the man is actually speaking. The reading off of the ribbon is done as occasion requires.

In this connection, reference is made also to the Swiss (C.F.F.) installations mentioned above, used for the examination of freight trains and carrying out brake tests.

g) *Radio communication for permanent way gangs.*

Most managements already have equipment of this type and report good results with it, especially in connection with maintaining permanent contact between gangs at work and the nearby traffic department offices. The D.B. emphasises these good results, especially in connection with gangs equipped with machines, and having means of travelling quickly from place to place, or which may be working over a considerable length of track. In this last case, radio links are set up between the different sections of the one gang.

The S.N.C.B. intends to use this type of portable apparatus in large stations for the protection of men engaged in clearing tracks after a snowfall.

Where the lookout man is somewhat far from the gang, the S.N.C.F. uses 3 portable sets of equipment, one at the station in rear, one close to the lookout man, and the third where the gang is working.

QUESTION 4. — *What factors led you to adopt radiophonic communication; for example, the length of trains and composition of train crews; the distance between signal boxes; or, in the case of radio between fixed points, was it to overcome physical difficulties and cost in providing land line communication?*

Mention has been made in connection with Question 3 of the *reasons* which have led the various Administrations to make use of radio telephony, such as saving in cost of installation compared with equipment requiring line wires or cables, and reduction of maintenance charges. In addition, they mention increased safety in cases where wired communication can be put out of order easily by atmospheric or other causes. The particular advantages offered in marshalling yards are cited as especially valuable in giving permanent communication with the drivers of shunting engines, enabling the official at the hump cabin to exercise direct and immediate control over the marshalling. Reliable radio communication saves much time, reduces the number and gravity of accidents during marshalling, and speeds up the clearance of the sorting sidings. It may be expected to bring also an increase in yard capacity without a corresponding one in construction costs, with at the same time a reduction in the number of staff required. Both the S.N.C.B. and S.N.C.F. propose, when introducing radio communication in their yards, to do away with many of the shunting signals, and so cut down first costs appreciably in new installations.

The *marking of wagons* prior to sorting ought also to be similarly accelerated by these means which must react on the overall capacity of the yard.

The use of radio by *permanent way gangs* should help to reduce as much as possible interruption to the work caused by passing traffic and so increase overall efficiency.

As will be shown later, not only have these objects been attained by using radio but many supplementary ones as well.

QUESTION 5. — *Have you used radiophonic communication in emergencies likely to affect the running of trains or safety of the line, with advantage over other means of communication and if so what are the advantages?*

Replies to this question show that the Administrations consulted have not as yet made use of radio for intervening immediately in case of emergency in the train working, but some of them agree that there is an *indirect effect on it* in that the possibility of communicating quickly between places leads to a saving of time.

QUESTION 6. — *What are the initial costs of this apparatus?*

What is the annual cost of operation subdivided into :—

a) *salaries and wages?*

b) *materials?*

c) *current?*

Particulars received regarding costs differ considerably between one management and another. *First costs* depend naturally on the type of construction, the power of the equipment, form of modulation used, etc., so that only a few particular examples can be cited. Thus, for example, the S.N.C.B. gives as a purchase price of a fixed set of equipment for a station having a power of 12 W, a figure of 7 000 Swiss francs and for a movable one about 5 800. The S.N.C.F. gives an overall figure for one fixed set and three sets on locomotives, spare parts included, of 38 500 Swiss francs. The C.F.F. quote a figure of 50 000 Swiss francs for a marshalling yard installation, working duplex with selective calling, and made up of one fixed post and four movable ones.

Costs of maintenance, where any are quoted, vary by 10 to 20 % of the first cost. Allowing for annual depreciation and taking a user of 10 years, an annual figure of the order of 20 to 30 % of first cost is obtained.

QUESTION 7. — *State route mileage served or areas covered and distances between fixed stations. In the case of mobile stations state the maximum distance involved between two mobile stations or mobile and fixed station.*

Distances and areas over which transmission is effected depend naturally in the first place on the transmitting power and the conditions obtaining between the transmitter and receiver. In addition the form and site of the aerial play an essential part. These distances are determined by the special conditions applying on a railway. For example the range of a radio installation in a marshalling yard is determined by the size of the yard, while the range of portable equipment used by permanent way gangs depends on the maximum distance they can be from the fixed point. Naturally these distances vary, but generally speaking, for marshalling yards a maximum range of 5 km (3 miles) has to be allowed for, and for portable equipment about 2 km (1.25 mile). However, when an apparatus is used at places where permanent way work is in hand the range will need to vary between 8 and 10 km (5 and 6 miles). With regard to the range of fixed installations, this can at times reach several hundred kilometres.

QUESTION 8. — *Please describe under each heading the type or types of apparatus employed supplying diagrams or photographs where desirable to illustrate the equipment.*

Except where they need to meet special requirements, as in the case of marshalling yards, the *equipment* used by various Administrations are similar for similar purposes. This is especially so with long range installations and portable apparatus.

For marshalling yard work, where the requirements are on the whole quite considerable, most of the makers have developed in conjunction with the different managements, special types of equipment able to stand up to the rough conditions met with.

To do this, they have started from the idea of adopting for both the fixed and movable equipment on the locomotives identical types of transmitter and receiver in order to make do with a relatively small number of types. Particulars received show that the power of transmission varies in marshalling yard work between 3 and 25 W. It is usual to employ frequency modulation, or in a small number of cases with amplitude modulation or phase modulation. Current for the fixed equipment is always taken from the ordinary local power supply, but the movable equipment is fed from a battery on the locomotive. The *power of portable sets* varies between 0.2 and 1 W, and source of current is generally an accumulator, but in some cases a dry battery. The weight varies from 3 to 11 kg according to the design and their use; it is, in general, determined by the weight of the battery.

Most of these marshalling installations date from since the last war, but in the long range type equipment provided during the war by certain military authorities is met with.

QUESTION 9. — *To what extent are inductive carrier or space radio systems utilised ?*

Only a few Administrations have answered this question, saying they cannot give any *rate of proportion between radio-telephonic and wired communication,* but that in certain areas it is not possible to replace the former by the latter, particularly where the distance between transmitter and receiver is variable.

QUESTION 10. — *State the frequencies used, the number of channels allocated and whether interference is experienced as a result of overlapping.*

The *range of frequencies* put at the disposal of the different managements come within those allocated to the particular country concerned at the International Conference on the distribution of wave lengths. In yards, frequencies generally correspond to a wave length of 2 or 4 metres, in some cases 8 metres. For long distance links, the Italian State Railways and the R.E.N.F.E. use frequencies situated between 2 and 10 MHz. Some managements have frequencies, however, in the ranges situated between 460 and 470 (Belgium), 510 and 540 MHz (Italy). The F.S. have observed differences in the frequency produced by changes in the heat of the atmosphere. Interference effects caused by reflection from undulations of the ground have been noted, in places by the Ö.B.B. when making trials with radio links between the front and rear of trains in deep cuttings.

QUESTION 11. — *State the method of obtaining licences, the name of the authority issuing such licences and whether any difficulty has been experienced in obtaining licences.*

QUESTION 12. — *Does the licencing authority impose any restrictions on the use of radiophonic communications systems for railway purposes ? If so, please state the nature of such limitations.*

QUESTION 13. — *Are any restrictions imposed by the licensing authority on the power output to be employed and, if so, do the limitations of output restrict the usefulness of the service ?*

These three questions relating to the issue of authority to operate radio-telephonic installations are dealt with together. In every country, *licences* are issued by the authorities having there the monopoly in telecommunications. In Germany and Austria, the issue of such licences is subject to the previous permission of the High-Commission or Inter-Allied Commission. The Ö.B.B. state that originally permission from this latter authority could not be obtained, but now, by virtue of a decision taken in March 1953, this has been granted, subject to certain restrictions.

In the various countries, requests for licences must be made separately for each installation to the competent authority or telecommunications department, where they are examined and dealt with according to the regulations in force. The Mediterranean-Niger Railway points out that in general the power vested in the telecommunications department is exercised by the competent military authority and that the post office is competent to deal only with installations in the General Management at Oujda.

The Italian State Railways state that they have to pay an annual fee to the postal department covering the working of their installations. Information received indicates that the various countries impose *restrictions on the use* of such installations in the sense that they may be used only for railway purposes and not be connected to the public telephone services.

As regards the *limitations of power*, they have all along been fixed in Germany at 10 W and in Austria at 3 W, within the range of 4 m waves. In Belgium, generally the figure is 50 W, in France 20 W and in the Netherlands 25 W for fixed installations and 15 for movable ones. Up to now, no inconvenience has been found to result from these restrictions. Spain, Italy and Cambodia report no limitation in the matter of power other than those resulting from International Conventions, while in the French Colonies and Switzerland, the maximum permissible power is laid down separately in each case.

QUESTION 14. — *How is reliable power supply ensured in all circumstances for mobile and fixed stations respectively?*

As indicated earlier, *power for fixed installations* is generally obtained from an outside public supply, but should this fail an emergency source is resorted to. These emergency installations are of the type already used for other railway purposes, and consist either of an internal combustion engine or an electric motor fed from a battery coupled to an A.C. generator of appropriate output. The equipment mounted on locomotives has no emergency facilities, the battery being considered to give sufficiently reliable service. Should it fail, however, then a reserve locomotive is substituted for the one on which the failure has occurred. Portable equipment fed by batteries likewise has no emergency current supply. It is therefore essential to make sure that it is in proper order before putting it into service.

QUESTION 15. — *What types of aerials are utilised on fixed and mobile stations?*

The *form of the aerials* is determined by the purpose to be served by the particular radio link one is used with. For fixed aerials the D.B. generally uses the dipole type or the λ/2, for movable installations it uses the whip or rod type λ/4, developed dipole aerial and particularly short aerials. Belgium uses aerial λ/2 (half wave) with vertical polarisation. Spain amongst others uses the Marconi « L » shaped type. There are also other aerials of the directional single conductor pattern.

Portable installations generally have the rod or whip type, sometimes also telescopic aerials and the S.N.C.F. uses for long distance work directional aerials mounted on light masts about 4 m (4 yards) high.

QUESTION 16. — *In the case of mobile units, have limitations imposed by the loading gauge created any difficulties in fitting aerials, especially to coaches, and how have these been overcome? Do these restrictions limit the range and coverage of the apparatus employed?*

Most Administrations use for equipment on vehicles aerials of special type able *to be kept within permitted clearances.* Losses of power arising from the nearness of the steel roofs and other metallic parts of the vehicles are according to most managements within acceptable limits. The Mediterranean-Niger Railway which contemplates working in future apparatus of much greater power (200 to 400 W) in order to overcome certain absorptions of power occasioned at present by the nearness of the vehicle roof, is to carry out trials with the object of collecting certain additional information on these losses.

QUESTION 17. — *In the case of « walkie-talkie » apparatus, what types of aerials and earth are utilised to ensure minimum interference with the movements of individuals carrying the apparatus?*

Administrations using portable equipment working within the 2 metre wave band use rod type λ/4 aerials. The case of the apparatus then forms the counterweight. Generally speaking, moving the equipment about has not been found to cause interference.

QUESTION 18. — *What methods are adopted to ensure continuity of signals when mobile stations are passing through tunnels or cuttings?*

This question raises a matter of the first importance for any extension of radio-telephony on railways and concerns the *conditions of reception* by trains in motion in situations where, according to experience gained hitherto, such is not possible in a straight simple manner, for example in deep cuttings in valleys surrounded by high mountains and in tunnels. Reports on this are to hand from two Administrations : the S.N.C.B. and the F.S., which have already made detailed investigations on this question.

The former gives particulars of numerous trials to investigate transmission in tunnels, in view of the special use of radio equipment contemplated for the Brussels area. In this case, it is a question of propelling by an electric locomotive a train having a steam locomotive in front. The driver of the latter has to observe the signals and give the necessary orders to the driver of the former. These trials have given the following results : In the case of a tunnel with a brick arch, even when curved, no appreciable diminution of reception power was noticeable, provided the frequency was at least 150 MHz. The tunnel was 1 km (0,62 mile) long. In tunnels lined with heavy reinforced concrete, transmission became interrupted when the locomotive had passed in by about 100 m (109 yards). The S.N.C.B. believes — and this agrees with the results of previous experiments — that reception can be improved by still further raising the frequency.

The F.S. have kindly forwarded a reprint entitled « Rendiconti della Riunione Annuale dell'A.E.I. » (Naples 1949) (Proceedings at the annual meeting of the A.E.I.) giving a review of the state of knowledge relative to communication between trains in motion and fixed points along electrified lines, up to that date. Research undertaken both before and after the war, in America, France and Italy, have led to the following results, shortly stated : The problem of communicating between trains and stations can be solved, when it is a question of open and not mountainous country, by the application of ultra-short waves and, on electrified lines, by using carrier current equipment.

The use of carrier current does in general, it is true, call for considerable improvement in the contact line as regards transmission of high frequencies. The system offers the disadvantage that in the event of an interruption to the contact line, the telecommunication arrangements become disturbed. By using free waves in the ultra-short range, the disadvantages of carrier current telephony can be obviated. This can be obtained also should there be gaps anywhere in the line circuit; it is possible at relatively small cost by using frequency modulation to create perfect communication throughout. This article contains also an account of a proposal based on the idea of establishing on the Milan-Naples line communication between 8 fixed points, having an average power of 100 to 200 W, and trains in motion. The scheme covers about 50 % of the total length of the line, 846 km (525 miles). Communication by ultra-short waves will give in addition the possibility of providing several channels.

Effecting connection between a communication network of this kind and the public telephone system is all the more essential in that over a great part of the distance there are only a relatively small number of fixed posts from which it is possible to connect up with that system.

The conditions governing the effecting of communication in tunnels are specially referred to in the article in question. It has been found that transmission on free waves is not possible in any length of tunnel at a frequency of 110 MHz, beyond a certain distance between posts. Trials have shown, moreover, that the range was greater in large than in small section tunnels. Tests made by the F.S. in July 1949 with frequencies of 250 to 540 MHz gave good results. Comparing these trials with those carried out by the S.N.C.F. after the war with a frequency of 1 420 MHz gave no appreciable improvement over the Italian ones made at 520 MHz. The article observes that the Italian Railways were taking up the construction of experimental equipment working on a frequency of 1 500 MHz with a view to continuing their investigation of this problem.

The Ö.B.B. mention, in connection with transmission in tunnels, trials effected in 1951 and 1952 on the Tauern line and in the Tauern tunnel itself with portable 160 MHz equipment and a power of 0.4 W for communicating between the front and rear of a train. It appears that in the Gastein valley, north of the tunnel, strong interference was experienced, due apparently to the reflection received from the neighbouring mountains. « Fading » was such that communication was completely interrupted although at certain points of the line the two posts were visible to each other. In the tunnel itself, it was found that over a distance of about 500 m (546 yards) between posts, communication ceased as soon as the head of the train was 20 m (21 yards) inside the tunnel, while its rear was yet far outside. By reducing the distance between the two sets of equipment to about 100 to 120 m (109 to 131 yards), reception proved possible during running in the tunnel and was almost as good as when the train was outside it. As these were purely qualitative tests and it was possible that the radio-active influence of the upper layers of air in the Gastein valley was not without effect, the Ö.B.B. contemplate continuing to investigate the conditions governing transmission in this region from a quantitative point of view.

QUESTION 19. — *Have any particular transmission difficulties been experienced in built-up areas as opposed to open country?*

Certain Administrations report *difficulties in transmitting* in built-up areas, particularly from stray current influence. Thus the S.N.C.B. has found the level of noise to be higher, although never sufficient to make hearing impossible. The S.N.C.F. state that such difficulties come from a shield effect, but no transmission troubles have been experienced in marshalling yards.

QUESTION 20. — *State whether interference is caused by metallic lineside structures causing loss of signals or fading. What steps have been taken to minimise these effects?*

A number of Administrations find « fading » to occur from the presence of large masses of metal along the line. The D.B. proposes to investigate this matter more thoroughly. The S.N.C.B. finds that « fading » can become so great as to cause signals to disappear. The particulars given by the Mediterranean-Niger Railway also are very interesting. This line has made tests at 2 to 8 MHz frequency and found signals to become feeble in consequence of certain masses of metal in the ground creating a form of « fading ». This weakening of the signals and recovery of their strength are however not sufficiently serious to prevent conversation being carried on.

The various managements see no other way of dealing with these phenomena save that of changing the location of the equipment, but in the case of movable apparatus, carried about in the neighbourhood of considerable masses of metal there appear to be no effective measures against fading.

QUESTION 21. — *Is any interference caused by electric traction and what steps have been taken to suppress it?*

According to reports *interference from electric traction circuits* is negligible with free waves and frequency modulation. The R.E.N.F.E. states that interference is experienced on the Madrid electric line when a train starts and continues until it has travelled about 500 m (546 yards). Amplitude modulation is used and it is probably in that circumstance that the cause of the high sensitivity to interference is to be looked for. The F.S. report noticeably increased sensitivity in the case of carrier type circuits.

QUESTION 22. — *State whether seasonal or weather conditions affect transmissions, i.e. snow, frost, fog, etc.*

While in Germany, Belgium, France and Switzerland, no noticeable effect has been observed from *climatic or seasonal variations,* Italy, Spain and the Netherlands have observed detrimental influences on the transmission. In Italy and Spain, this was in the case of long distance communication. It is proposed in Italy to combat such temporary influences by selecting suitable frequencies for use during certain hours, or periods of the year.

When ice is present no effect is observable with free waves but there is with carrier current.

In the tropics climatic conditions exercise an appreciably greater effect. The Mediterranean-Niger line reports considerable disturbances during sand storms; the particles of sand release their static electrical charge to the aerials and the disturbed balance causes crackling sounds, varying from one second to a continuous buzzing. The intense heat of summer — up to 40° C in the shade — also has an unfavourable influence on the communication. Cambodia states that in the rainy season from May to November storms can cause disturbances of the order of 15 and even 20 hours.

QUESTION 23. — *How has noise interference been overcome on moving locomotives, especially steam locomotives, and what calling devices are utilised? Are loud-speakers and independent microphones used for receiving and transmitting messages and is reception of signals satisfactory in all conditions?*

Do you provide a duplicate hand set on a locomotive, for use by a shunter to obviate the latter mounting the footplate?

To counter the relatively *high level of noise* obtaining *on locomotives* where communication is made directly with the driver, and where consequently the equipment is installed in the cab, some managements, such as the D.B. and S.N.C.B., use loud-speakers of the horn type, with microphone and compression chamber, whilst others employ separate microphones and loud-speakers. In all cases where loud-speakers are used, the receiver has a higher output at the low level ranges determined either by the maximum sound capacity of the loud-speakers (100 phons measured at a distance of one metre in the case of the S.N.C.B.) or by its power (10 W on the F.S.).

Some managements do not mount the equipment in the cab. For example, the C.F.F. mount it on the footplate framing (with hand receiver in a protective box) and the Mediterranean-Niger Railway fits the apparatus in a special separate compartment in the train.

Calling is effected, except in the case of long distance links, as a rule verbally, but in a few instances by morse code signals. The D.B. portable equipments use calling on a frequency of 1 750 Hz. According to reports, no special apparatus for the use of shunting staff is in service.

QUESTION 24. — *When a fixed station is operating to a number of mobile stations, what method is employed for calling and identification of those stations, i.e. is selective dial calling utilised?*

Two *types of calling* are in use where a fixed post is in communication with several movable ones. One is that used by the D.B. under the name of « Kreisverkehr » (general call). In this system, all the various locations are in the normal condition connected ready to receive. When one of them makes a call it connects its own transmitter in circuit and cuts out its receiver by moving a switch and all the other locations receive the messages spoken. In each marshalling yard installation, a different frequency is laid down for these cases and the fixed posts, as well as the movable, can adjust themselves to work on the frequencies of other marshalling yard installations.

Other managements use selective calling, either by means of a dial or by operating various push-buttons which cause combinations of sounds to be emitted, corresponding to the post to which it is desired to speak, the required frequency being selected. These two methods, general or selective calling, have given good results in practice.

QUESTION 25. — *What is the organisation adopted for maintenance and servicing of the radio apparatus and how does the cost compare with other forms of telecommunications?*

Is maintenance performed by railway or outside staff?

Administrations which have radio installations already in service as a rule *maintain* them by their own specialist staff. In certain exceptional cases, however, the small ordinary day to day maintenance is attended to by the railway staff, only overhaul of the equipment being entrusted to firms. The S.N.C.F. for example reports that the cost of a general overhaul amounts to 5 % of the initial price. The other managements, with the exception of the S.N.C.B., have provided no figures on this subject. Some, for instance the F.S., are of the opinion that maintenance costs are approximately the same as for ordinary wire telecommunication circuits, whilst others, such as the C.F.F. think they are higher. The facts arrived at by the S.N.C.B. provide interesting information concerning the number of hours taken up by maintenance and the annual overhaul, grouped in the following table :

Type of installation	Number of hours occupied by maintenance work per period stated					Total number of hours per annum
	weekly	monthly	every 3 months	every 6 months	annually	
Fixed marshalling yard post		6			16	88
Portable marshalling yard post			10	32		104
Portable transmitter-receiver set, S.R. 610			4	6	8	36
Portable transmitter-receiver set	1	2			10	86

The S.N.C.B. considers that it is not possible to establish a correct comparison in this matter between radio and other telecommunication installations, seeing that in many cases the former cannot be replaced by the latter, notably of course in the case of connections between fixed and movable posts. This point of view has of course to be accepted; however, it would be desirable to know what the ratio is between the two in those cases where the radio installations can be compared with the ordinary type which they have supplanted. Considerable weight should therefore be attached to the opinion of the F.S. which, thanks to their extensive radio network, seem to possess the greatest experience in Europe in this field, and who, as stated above, consider there is no difference in this respect between the two types.

QUESTION 26. — *What methods are adopted for training operational and maintenance staff?*

Most Administrations form their *maintenance staff* themselves by special courses of instruction, or by requiring those concerned to undertake one at a manufacturer's works. In accordance with prevailing economic tendencies, specially capable men are selected for this work, if possible from those already possessing some knowledge of radio equipment. The training courses vary from 14 days to 50 half days.

It depends essentially on the number of installations of differing type which a man may be called on to maintain.

As regards *operating staff,* all managements have made every effort to render the manipulation of the equipment as simple as possible, so reducing the training required to a minimum. Some of them effect this by placing with the operator for a certain length of time a technically qualified man, familiar with the installation.

QUESTION 27. — *Have you a radiophonic communication system to or from moving trains for use by the travelling public? It is assumed that any such service is applicable to long distance passenger trains only. What is the method of calling, the basis and method of raising charges and the extent to which there is a demand for the service? Is this service an economic proposition?*

The question of setting up connection between trains in motion and fixed points with the idea of offering to passengers the possibility of being connected while travelling to the public telephone system is being investigated by the D.B., S.N.C.F. and F.S. The S.N.C.B. states that in 1949, the Belgian Railways made experiments with such an arrangement in conjunction with the Post & Telegraph Department, but the trials were not continued in view of the fact that fitting the trains with it did not pay. In addition, the short length of the lines on Belgian territory makes the runs short also, and hardly any need is felt for passengers to put themselves into communication with the public telephone network.

The manner in which the F.S. propose to deal with this problem as part of the whole question of the application of radiotelephony to railways has been pointed out above in the reply to Question 18, when referring to proposals to instal radio installations along the Milan-Naples line.

QUESTION 28. — *Is radio apparatus employed for controlling signals in lieu of an attendant?*

All managements replied to this question in the negative.

QUESTION 29. — *Are any radio teleprinter or facsimile systems in use?*

The R.E.N.F.E. report that they are to use the Coquelot teleprinter system, while the F.S. use the Siemens « Hellschreiber » as zone teleprinter experimentally.

QUESTION 30. — *Are there any other spheres not mentioned above in which you utilise radio? If so, please describe fully.*

The D.B. reports that trials are in progress for the setting up of *remote control of vehicles* and for radio transmission of telegrams and money orders. The C.F.F. are thinking of using radio in connection with the maintenance of high tension lines and removing faults on them.

QUESTION 31. — *Has the use of radio superseded previous means of communication or is it supplementary to existing methods?*

No management reports having replaced ordinary communication circuits by radio. On the contrary, the general statement is that radio is applied as complementary to the main telecommunication system. Only in the case of certain communication links, used hitherto for safety reasons, has there been some change in this respect on the S.N.C.B. and S.N.C.F., in the sense that since the introduction of radio in the marshalling yards, the use of shunting signals of ordinary type has been given up when constructing new yards.

QUESTION 32. — *Is radiophonic communication reliable in service? Specify any disadvantages especially in relation to breaks in continuity of the service stating the more common causes of failures.*

Generally speaking the view is that radio communication is reliable. Any *inconvenience* arising from interruptions is due partly to atmospheric disturbances, but also sometimes to certain parts of the equipment not being sufficiently well made. In certain kinds of service, where these parts are subject to particularly heavy mechanical stresses and it has not proved possible to meet the resulting conditions, breakdowns are still to be reckoned with. The opinion of most Administrations is that failures are, on the whole, within acceptable limits. They are mostly caused by contacts becoming defective, wires breaking, wear and tear accumulating on valves, insufficient source of current and defects in condensers and resistances. The S.N.C.B. says that at one time when the radio apparatus was put into service the total interruptions amounted to some 4 to 5 %, but thanks to the constant instruction given to the staff, these have now been brought down to 1 % and it is hoped to reduce them further to 0.5 %. This management also states that 70 % of all failures are attributable to the valves, 19 % to relay defects and 10 % to the want of stability in the power supply.

QUESTION 33. — *Describe in detail the benefits to railway operation and economies accruing from the utilisation of radiophonic communications systems.*

All managements are agreed that radio offers advantages unobtainable by other means of communication. As stated above in several places, this is so in all cases where the distance between transmitter and receiver is variable. It is in the possibility of being able to keep in constant touch with each train and each vehicle, even especially each motor vehicle, as well as being able at any moment to give orders directly to staff, which can be carried out in a sure and speedy manner, that the managements see *advantages* which affect the entire railway service, quickening it up and rendering it more economic. These advantages may be summarised briefly as follows :

1) Use of radio-telephony in marshalling yards.

a) Quickening up of the sorting movements leading to a saving in locomotive hours and staff working time, more rapid making up of trains and release of the various sidings, both formation and departure, and hence increase in the capacity of existing yards, from which comes a further economy in costs in all cases where an extension to the tracks would otherwise be indispensable to deal with the growth of the traffic.

b) Efficiency of a yard remains almost normal when visibility is reduced (fog, snow, storms) on curved tracks and in darkness.

c) Better effect on the speed of shunting than with ordinary signals allows of taking better account of the nature of the freight and avoids in greater measure damage to consignments. Should a derailment occur, the working can be stopped at once and damaged vehicles and their contents kept down to a minimum.

d) Thanks to being able to communicate directly with the drivers, misunderstandings likely to arise in the course of the transmission of orders are eliminated.

e) Savings resulting from getting rid of the cost of installation and maintenance of special shunting signals when building new yards.

These savings have been set out in a very detailed manner by certain managements. The gains, specified in figures, resulting from the use of radio have only been able to be given approximately by the S.N.C.F., which indicates a gain of 1/3rd in efficiency over previous methods of shunting operation. Some managements consider, as is practically incontestable, that the economic aspect of an installation requires to be calculated specially in each case.

2) Use of radio in connection with permanent way gangs.

This gives a certain and permanent means of communication with a gang. Those responsible can thus order directly, and in good time, the clearing of the track, and this reduces the interruptions to the traffic. On lines where telephone circuits are cabled, the necessity hitherto felt of transporting cable drums to which to connect the portable equipment at the nearest convenient point is eliminated.

3) Use of radio between trains in motion and fixed points along the line.

It is not yet possible to express an opinion on the suitability and economy of such links, which, according to the reports, have been established only in Europe experimentally as yet. Everything permits of thinking however that with a new development in this technique, this will lead to more economic traffic operation.

Managements outside Europe are using this type of equipment with advantage to ensure the safety of their trains. It permits of taking decisions quickly in case of any mishap or unusual occurrence. A special advantage is considered to be that the construction and maintenance of a system of communication of this kind effected by wire lines or cables in certain conditions would absorb considerable sums.

QUESTION 34. — *Do you consider the reliability of the service and the benefits accruing justify the adoption of radiophonic communications systems as a permanent feature in all or particular spheres and is it your intention to extend the practices?*

Replies to this question indicate that those managements which have had radio installations in service for some time, and been able to observe their working, are all agreed that their use in the present fields is fully *justified,* notably where the same object could not be attained except at very great cost or even not at all, using other methods of telecommunication. Some Administrations, amongst them the D.B., S.N.C.F., F.S. and C.F.F., consider that these installations will become applicable in the future to other branches of railway working, if savings can be effected by so doing. For this, however, it appears that certain technical improvements are required in constructional details. All the same most managements are not contemplating at the moment an extension of radio telephony, except in the form of an increase in the number of installations meeting purposes for which they have already proved their value.

QUESTION 35. — *Have you under consideration, but not yet developed, the application of radio to any other phase of railway operation? Have you made use of radar or do you contemplate doing so?*

Some managements are proposing to make other applications of radio. Thus the D.B. speaks of using remote control of vehicles, for example, electric shunting locomotives, as well as C.T.C. by radio on secondary lines, endeavouring to transmit in this way conversation, selective calling and cab signals, and to give an indication automatically of the position of a train. The OTRACO sees a new field for radio in effecting a link between the locomotive and the train dispatcher, or traffic controller, carried out by radio between the locomotive and the nearest post and thence to the dispatcher. The F.S. also is obtaining economic advantages from connections between the trains and fixed points and from using radio for repeating signals on the locomotive.

Radar installations, as used regularly now on board ship, have not yet been employed. The D.B. reports however that it is fitting an installation on a ferry vessel.

* * *

Summing up, it results from the information collected at considerable trouble by the various managements, that at the present moment the general radio telephonic installations at work or those that have been tried, have on the one hand opened up a new opportunity of making the best economic use of existing means of working and, on the other hand, of contributing to reduce the cost which would be necessary to put in ordinary methods of telecommunication. It appears, considering the whole of the opinions expressed, that new and better chances of using radio equipment are opening up, but that more thorough technical investigations are still required and certain items of equipment need to be improved. Such extensions of radio to new applications have been favourably received and in no case has there been any opposition, while efforts are being made to use it more largely in fields where it has already been introduced. A fact not to be neglected is that to introduce it into branches so far untouched will often call for managements adapting their working instructions to the new modified conditions. Thus certain inevitable considerations which, from the fact that each management is rather conservative, a result of the nature of things and by no means unjustified, lead to a certain hesitation when it comes to introducing equipment which positively revolutionises the accepted methods of working.

On the other hand, the economic results experienced in certain fields of working cannot be set aside less than ever today when every management feels in growing fashion the competition of other means of transport and finds itself obliged to cut down on its own operating costs.

PART II.

Technical considerations.

In this second part the technical features of the apparatus are shown to the extent that information has been provided by the different managements or has come to the knowledge of the author of this report.

In paragraph 1 of Part II, dealing with constructional details of the wiring and cabling of installations, as well as the methods of fitting, preference has been given to sub-dividing according to the order of objects for which a particular installation is used, which permits of more easily comparing the applications of different types.

Paragraph 2, on the contrary, groups the information obtained from the particulars provided, which have not been taken up in any general form in the first part.

* * *

1. DETAILS OF CONSTRUCTION OF RADIO SETS AND ACCESSORIES USED WITH THEM.

1.1. Communication between trains and fixed points.

1.1.1. *German Federal Railways (D.B.).*

Object : Communication between assisting engine and block or other signal boxes.

1.1.1.1.	*a)*	Type of apparatus . . .	Portable radio sets.
		H.F. ranges	70.025 ÷ 70.750; 80.025 ÷ 80.75; 165.7 ÷ 166.0; 170.2 ÷ 170.5; 166.1 ÷ 166.8; 170.6 ÷ 171.3 MHz.
		B.F. range	200 ÷ 3 000 Hz.
	b)	Emittive power	0.2 ÷ 0.4 W.
		Modulation	Frequency.
		Tuning range	10 ÷ 12 kHz.
		Frequencies	Maximum of 3.
		Frequency control . . .	Quartz.
		System	Simplex.
		Range	5 km (3 miles) maximum.
	c)	Calling	by resonant tone at 1 750 Hz.
	d)	Speech transmission . .	Micro-telephone with push button in hand set to change from receiving to transmitting.
	e)	Aerials	Steel tape λ/4 (quarter wave) for movable equipment; for fixed equipment and on locomotives, the same as used in marshalling yards (which see).
1.1.1.3.	*a)*	Power supply	For portable equipment : batteries. For fixed equipment : trickle charged batteries or outside supply.
	b)	Characteristics	Capacity : 6.5 ÷ 9 Ah, sufficient for 5 ÷ 8 hrs.

1.1.2. *Mediterranean-Niger Railway.*

Object : Permanent communication with moving trains for train dispatching purposes.

1.1.2.1.	*a)*	Type of apparatus . .	Fixed (not portable).		
		H.F. ranges	6.5 ÷ 7.0 and 5.5 ÷ 6.0 MHz by day. 3.0 ÷ 3.5 and 3.5 ÷ 4 MHz by night.		
	b)	Emittive power	Fixed apparatus	Movable on trains	Movable on railcars
			60 ÷ 80 W	20 W	35 W
		Modulation	Push-pull; the H.F. level functions in class C and is modulated on the anodes and protective grids by a push-pull modulator functioning in class AB 2.		Push-pull; the B.F. level functions in class C and is modulated on the control grids by a 5 W modulator.
		Stability	2.10^{-4} o for a band variation of ± 8 %.		
		Degree of modulation	up to 80 %		up to 65 %
		Range	about 100 km (62 miles)		
		System	Simplex.		
	c)	Calling	By tone over 8 W loudspeaker	......	By tone over 5 W loudspeaker.
	d)	Speech transmission . .	Carbon microphone.	Carbon microphone with push button for transmitting.	
			...	...	Micro-telephone in parallel with that.

			Fixed apparatus	Movable on trains	Movable on railcars.
			Loudspeakers or receivers.	Receivers.	
	e)	Type of aerial	Hertz — Windom $\lambda/2$ (half - wave) Aerial selected by dialling according to the frequency. Sensitivity to direction given. Counterpoise or earth formed of group of wires connected to earth.	Wire stretched between the ends of the vehicle. Length : 14 m (15 yards). The mass of the installation is linked to the frame of the vehicle. Same aerial for reception as for transmitting with relay change-over.	25 m (27 yards).
1.1.2.3.	*a)*	Power supply	Outside supply with 1. KVA buck-boost transformer.	Lead-acid battery with about 6 hrs reserve.	Battery.
	b)	Characteristics	110 V, 50 Hz.	12 V, 90 Ah for transmitter : generating motor 12/500 V 0.200 A. For receiver : generating motor 12/200 V 0.100 A. Heating by a 12 V. battery.	24 V, 450 Ah, for transmitter : generating motor : 24/1200 V, 0.3 A. For receiver : generating motor 24/300 V, 0.100 A. Heating by a 24 V. battery.
				Antiparasite for all electric apparatus.	

1.1.3. *Italian State Railways (F.S.).*

Object : Communication with trains for service purposes and between passengers and the public telephone service (long distance trials).

Details made known concerning trial equipment :

1.1.3.1.	*a)*	H.F. range	110 MHz.
	b)	Emittive power	30 W.
		Modulation	frequency.
		Number of channel . .	1.
		Range	34 km (21 miles).

1.1.4. *Royal Cambodian Railways.*

Object : Communication with trains for service reasons and to provide safe working.

1.1.4.1.	*a)*	H.F. ranges	4.270 and 2.6925 MHz.		
			S.R.A.T. ER 360	S.R.A.T. ER 315	W.S.M.K. III 19
	b)	Emittive power	60 W	15 W	20 W
		Modulation	amplitude.		
		Frequency control . . .	quartz.		
		Range	50 km (31 miles) maximum.		
	c)	Calling	Audible.		
	d)	Speech transmission . .	Loudspeakers and receivers for reception. Microphone with push-button for transmission.		
	c)	Aerials	Single wire and whip type.		

1.1.4.3.	*a)*	Power supply	In the towns of Pnom-Penh (220 V) and Battambang (110 V), local A.C. supplies; Elsewhere : accumulators and generators.
	c)	Characteristics	Accumulators : 6 V, 150 Ah, cadmium nickel. Charging units : 12 V, 300 W.

1.1.5. *French National Railways Company (S.N.C.F.).*
Technical reports show that the S.N.C.F. had made trials before the last war, taking them up again after it. In these later trials were used :

1.1.5.1.	*a)*	H.F. range	1 420 MHz.
		Emittive power	4 W.

The trials were carried out on lines on which there were tunnels and up and down gradients. The distances were 1 200 to 1 550 m (1 312 ro 1 640 yards). « Horn » type aerials were used.

1.2. Communication between staff on a train.

1.2.1. *Austrian Federal Railways (Ö.B.B.).*
Object : Communication between train engine and assisting engine (trials on mountain lines).

1.2.1.1.	*a)*	Type of apparatus . .	Portable sets.
		H.F. range	156 ÷ 168 MHz.
		B.F. range	300 ÷ 4 000 Hz.
	b)	Emittive power	0.4 W.
		Modulation	Frequency.
		Range of tuning. . . .	± 15 kHz.
		Frequency control . . .	Quartz.
		System	Simplex.
		Gap between channels .	100 kHz.
		Sensitiveness of reception	1.5 V for an interval of 20 db.
		Weight	about 6 kg (13 lbs.).
	c)	Calling	by resonant tone 1 750 Hz.
	d)	Speech transmission . .	Micro-telephone with push-button changeover from reception to transmission.
	e)	Aerials	λ/4 (quarter wave) steel tape, for both transmission and reception.

1.2.1.2. The apparatus is installed on locomotives as occasion requires.

1.2.1.3.	*a)*	Source of power. . . .	Accumulators and vibrator, or local supply.
	b)	Characteristics	Heating : 2 V, 9 Ah; anode feed : 4 V, 13.5 Ah sufficient for about 8 hrs. transmission of 20 %. Equipment working from local supply from 110 to 220 V, 50 Hz.

1.2.2. *Belgian National Railways Company (S.N.C.B.).*
Object : as given in 1.2.1. (trials in tunnels).
No information available regarding this equipment.

1.3. Radio-telephony in marshalling yards.

1.3.1. Communication between a fixed point and the locomotive.

1.3.1.1. *German Federal Railways (D.B.).*

1.3.1.1.1.	*a)*	Type of equipment . .	Fixed (not portable) apparatus.
		H.F. ranges	70.025 ÷ 70.750 MHz; 80.025 ÷ 80.750 MHz.
		B.F. ranges	200 ÷ 3 000 Hz.

	b)	Emittive power	hitherto 10 W; in future 3 W.	
		Modulation	frequency (F.3).	
		Tuning range	10 ÷ 12 kHz.	
		Frequencies	maximum of 6.	
		Gap between channels	at present 100 kHz; in future 50 kHz.	
		Frequency control	Quartz.	
		System	Simplex.	
	c)	Calling	by voice.	
	d)	Speech transmission	Microphone loudspeaker. Special push-button for changing over from reception to transmission.	
	e)	Aerials	Fixed equipment : dipole or arrestor head (Sperrkopf) type $\lambda/2$ (half wave).	Movable equipment : Rod or developed dipole $\lambda/4$ (quarter wave) special short height pattern 320 mm (12.59 inches).
1.3.1.1.2.		Arrangement	Transmitter and receiver either at the end of the locomotive or at the side, by footplate steps.	
1.3.1.1.3.	a)	Sources of power	Fixed equipment. From main supply.	Movable equipment. On steam locomotives : (24 V) turbo-generator; on electric locomotive : 24 V battery.
	b)	Characteristics	Power of turbo-generator : 500 W. Batteries on electric locomotive have about 180 Ah capacity.	
1.3.1.2.		*Belgian National Railways Company (S.N.C.B.).*		
1.3.1.2.1.	a)	Type of equipment	Fixed (not portable) apparatus.	
		H.F. ranges	38.7, 38.8 MHz. 158.160, 162.840, 162.960. 163.440, 166.080, 166.200 MHz. 460 ÷ 470 MHz (intended but not as yet in use)	
		B.F. ranges	300 ÷ 3 600 Hz.	
	b)	Emittive power	Bendix, fixed set : 50 W; movable set : 12 W; Pye, fixed set : 12 W; movable set : 5 W.	
		Modulation	Bendix : frequency, Pye : amplitude.	
		Frequencies	either 2 or 5.	
		System	Simplex.	
	c)	Calling	by voice.	
	d)	Speech transmission	Loudspeaker and microphone; on locomotives also hand sets. Push-button changeover from reception to transmission.	
	e)	Aerials	Fixed equipment : $\lambda/2$ (half wave) with vertical polarisation. On locomotives : « ground plane » type.	
1.3.1.2.2.		Bendix system	Transmitter and receiver on cab roof.	
1.3.1.2.3.	a)	Source of power	Fixed equipment : From main supply.	Movable equipment : 24 V 500 W D.C. turbo-generator, specially stabilised voltage. 24 V, battery fed to rotary converter set furnishing A.C. voltage.

1.3.1.3.		*Spanish National Railways (R.E.N.F.E.)*	
1.3.1.3.1.	*a)*	Type of equipment . .	Fixed (not portable) apparatus.
		High frequency ranges .	30 ÷ 60 MHz and 300 ÷ 2 700 MHz.
	b)	Emittive power	25 W.
		Modulation	frequency.
		Method of transmission.	Simplex.
	c)	Calling	by voice.
	d)	Speech transmission . .	by microphone.
	e)	Aerials	Fixed equipment. Vertical $\lambda/2$ (half wave). Movable equipment. Vertical $\lambda/4$ (quarter wave).
1.3.1.3.2.		Fixed equipment in the hump post (poste de butte); movable, on the locomotive, protected against shock, vibration, heat and damp.	
1.3.1.3.3.	*a)*	Source of power. . . .	Local supply or batteries for fixed equipment; batteries for movable.
1.3.1.4.		*French National Railways Company.*	
1.3.1.4.1.	*a)*	Type of equipment . .	Fixed (not portable) apparatus.
		H.F. ranges	156 ÷ 174 MHz.
	b)	Emittive power	8 to 10 W.
		Modulation	Frequency.
		Frequencies	up to 6.
		Frequency control . . .	Quartz.
		System	Simplex.
	c)	Calling	by voice, either way.
	d)	Speech transmission . .	Microphone with push-button changeover from reception to transmission; loudspeaker.
	e)	Aerials	$\lambda/2$ (half wave) folded in horn shape; « ground plane » formed of 4 bars $\lambda/4$ (quarter wave).
1.3.1.4.2.		Fixed equipment. . . .	On desk or wall in hump post (poste de butte).
		Controlling apparatus.	Fitted with 3-position switch, « off » « heating » and « operating », frequency switch. Voltage indicating lamp, Microphone on support in position to catch voice of shunting supervisor, Aerial on signal box roof, if need be raised on a post, Different items (transmitter, receiver, and feed equipment) connected by cables and plug connectors.
		Movable equipment on locomotive	Transmitter and receiver mounted on cab side with elastic suspension. Aerial at front of locomotive. Controlling apparatus above the desk within voice range of driver. Connections by armoured cables.
1.3.1.4.3.	*a)*	Source of power. . . .	With fixed equipment, the local supply (110 ÷ 220 V, 50 cycles). For movable apparatus, two converter sets for anode tensions of the receiver and transmitter.
1.3.1.5.		*Italian State Railways (F.S.).*	
1.3.1.5.1.	*a)*	Type of equipment . .	Fixed (not portable) type S.C.R., 552 modified.
		H.F. range	156 MHz.
		B.F. range	300 ÷ 5 000 Hz.

	b)	Emittive power	8 W.	
	c)	Calling	By voice or morse signals over loudspeaker. Receiver with B.F. 10 W low frequency output.	
	d)	Speech transmission	Electro-dynamic loudspeakers and microphones.	
	e)	Aerials	λ/2 (half wave) « ground plane » type.	
1.3.1.5.2.		The fixed equipment is placed in the signal box, the movable on the locomotive, spring suspended.		
1.3.1.5.3.	*a)*	Source of power	Fixed equipment : local supply	Movable equipment : locomotive battery and motor generator.
	b)	Characteristics		150 Ah capacity.
1.3.1.6.		*Swiss Federal Railways (C.F.F.).*		
1.3.1.6.1.	*a)*	Type of equipment	Fixed (not portable) apparatus.	
		H.F. range	34.4 and 38.8 MHz.	
	b)	Emittive power	25 W.	
		Modulation	Push-pull.	
		Frequencies	2.	
		Oscillator	Quartz.	
		System	Duplex.	
	c)	Calling	By selective dial. Hooter for movable equipment (on locomotives) and bell for fixed equipment.	
	d)	Speech transmission	Micro-telephone.	
	e)	Aerials	Fixed equipment : Dipole type.	Movable equipment : Whip type.
1.3.1.6.2.		Fixed equipment	In hump post (poste de butte).	
		Movable equipment	On side of locomotive accessible from the ground.	
1.3.1.6.3.	*a)*	Source of power	Fixed equipment : local supply.	Movable equipment : locomotive battery via converter set.
1.3.1.7.		*Colonial Transport Operating Department (OTRACO).*		
1.3.1.7.1.	*a)*	Type of equipment	Fixed (not portable) Motorola type.	
		H.F. range	152 ÷ 174 MHz.	
	b)	Emittive power	10 W.	
		Modulation	Frequency.	
		Tuning range	± 15 KHz.	
		Frequency control	Quartz.	
		Sensitiviness of receiver.	0.6 V for an interval of 20 db.	
		Frequencies	2.	
	c)	Calling	Selective and general, by means of call push-buttons.	
	d)	Speech transmission	Microphone and loudspeaker.	
	e)	Aerials	Vertical in all cases.	
1.3.1.7.3.	*a)*	Source of power	Fixed equipment : local supply and trickle charged battery.	Movable equipment : locomotive battery.

1.3.2. **Communication between wagon marker and hump cabin.**

1.3.2.1. *German Federal Railways (D.B.)* (Trials).

1.3.2.1.1.	*a)*	Type of equipment	Portable : Teleport II, Telefunken	Funkstat la Siemens & Halske	KL. 2 Lorenz	Portafon 6 Huber & Brendel. (No details available).
		H.F. range	cf. 1.2.1.	156 ÷ 174 MHz.	30 ÷ 170 MHz.	
		L.F. range		300 ÷ 3000 Hz.		
	b)	Emittive power		0.5 W.	0.3 W.	
		Modulation		Frequency.		
		Tuning range		± 15 kKz.	± 17.5 kHz.	
		Frequency control		Quartz.	Quartz.	
		System		Simplex.	Simplex.	
		Gap between channels		100 kHz.	150 kHz.	
		Sensitiveness of receiver		3.6 μ V.	1 μ V.	
		Weight		8 kg.(17 lbs).	4.3 kg.(9 lbs.)	
	c)	Calling	tone, at 1 750 MHz.			
	d)	Speech transmission		Micro-telephone with push-button changeover from reception to transmission.		
	e)	Aerials		Tape $\lambda/4$. (quarter wave).	Tape $\lambda/4$. (quarter wave).	
1.3.2.1.3.	*a)*	Source of power		Batteries.	Batteries.	
	b)	Characteristics		Heating battery, 1.5 V, 20 Ah; for converting to A.C. 6 V, 20 Ah. Capacity 8 hr. at 20 % transmitting and 80 % receiving.	Edison type accumulator and vibrator. 4 to 5 hours capacity.	

1.3.2.2. *French National Railways Company (S.N.C.F.)* (Trials)

1.3.2.2.1.	*a)*	Type of equipment	Portable and non-portable.	
		H.F. range	31.7 ÷ 41 MHz.	
	b)	Emittive power	Fixed equipment : 20 W.	Portable equipment : 0.3 W.
		Modulation	Amplitude.	
		System	Duplex.	
		Frequencies	Maximum 6.	
	c)	Calling	By voice for movable equipment on common frequency. Each portable equipment calls the fixed post on its frequency.	
	d)	Speech transmission	Micro-telephone and loud-speaker.	Loudspeaker with directable microphone.
	e)	Aerials	Transmitting aerial $\lambda/4$ with as many such for receiving as there are frequencies (quarter wave).	$\lambda/4$ (quarter wave).

1.3.2.2.2.		Method of fitting	Not yet definitely decided.	On a frame carried in front of the operator himself.
1.3.2.2.3.	*a)*	Source of power	Local supply.	Battery and vibrator.
	b)	Characteristics		Accumulator : 2 V, 12 Ah. Capacity : 4 ÷ 5 hours.

1.4. **Radio-telephony for other purposes.**

1.4.1. *Communication with permanent way gangs.*

1.4.1.1.1. *Belgian National Railways Company (S.N.C.B.).*

1.4.1.1.1.	*a)*	Type of equipment	a) Teleport II portable. (see 1.2.1.).	b) Motorola, no details available.

1.4.1.2. *French National Railways Company (S.N.C.F.).*

1.4.1.2.1.	*a)*	Type of equipment	Portable.
		H.F. range	156 ÷ 174 MHz.
	b)	Emittive power	2 W.
		Modulation	Frequency.
		Frequency control	Quartz.
		System	Simplex.
		Weight	11 kg. (24 lbs.) with batteries.
	c)	Calling	By voice, reception over loudspeaker, audible over several yards distance.
	d)	Speech transmission	Micro-telephone with push-button changeover from reception to transmission. Possibility of connecting a small loudspeaker to the apparatus.
	e)	Aerials	λ/4 folded (quarter wave) (double with three elements).

1.4.1.2.2. Equipment mounted on a light metal post fixed to the ground by a special attachment.

1.4.1.2.3.	*a)*	Source of power	2 lead-acid accumulators, one for heating, the other for providing the anode voltage through a vibrator.
	b)	Characteristics	Capacity of each battery : 28 Ah; voltage 6 V. Plexiglas containers with liquid absorption.

1.4.1.3. *Italian State Railways (F.S.).*

1.4.1.3.1.	Types used	Handie-Talkie 3 ÷ 4 MHz. Walkie-Talkie Bc 695 B : 0.5 W, 31 MHz. Bc 1 000 A : 0.5 W, 40/48 MHz. Feldu : 0.5 W, 180-240 MHz.

1.4.1.3.3. Portable equipment fed from dry batteries or alkaline Fe-Ni cells.

1.4.1.4. *Netherlands Railways (N.S.).*

1.4.1.4.1.	*a)*	Type of equipment	ECKO wireless No. 88 portable type.
		H.F. range	40.4 and 40.9 MHz.
	b)	Emittive power	1 W.
		Modulation	Frequency.
		System	Simplex.
	c)	Calling	By voice.
	d)	Speech transmission	Micro-telephone.
	e)	Aerials	Rod type.
1.4.1.4.3.		Source of power	Dry batteries.

1.4.1.5. *Swiss Federal Railways (C.F.F.).*

1.4.1.5.1.	*a)*	Type of equipment . .	Portable.
		H.F. range	70 MHz.
	b)	Emittive power	0.5 W.
		Modulation	Amplitude.
		System	Simplex.
	c)	Calling	By voice.
	d)	Speech transmission . .	Micro-telephone.
	e)	Aerials	Whip type.
1.4.1.5.3.		Source of power. . . .	Dry cells, 8 to 10 hour type.

1.4.2. *Communication between driver and wagon examiner (brake tests).*

1.4.2.1. *Swiss Federal Railways (C.F.F.).*

1.4.2.1.1.	*a)*	Type of equipment . .	Portable, Handie-Talkie pattern.
		H.F. range	24 MHz.
	b)	Emittive power	0.1 W.
		Modulation	Amplitude.
		Frequency control . . .	Quartz.
		System	Simplex.
		Weight	2.5 kg (5.5 lbs.).
	c)	Calling	By voice.
	d)	Speech transmission . .	Microphone and telephone.
	e)	Aerials	Whip type.
1.4.2.1.3.		Source of power. . . .	Dry cells.

1.4.3. *Communication between fixed points (radio links).*

1.4.3.1. *German Federal Railways (D.B.).*

1.4.3.1.1.	*a)*	Type of equipment . .	Fixed (not portable) apparatus.		
		H.F. range	41 ÷ 68 MHz in two partial ranges.		
		Transmitting range. . .	Up to 120 kHz.		
	b)	Emittive power	50 W.	250 W.	1.5 W.
		Modulation	Frequency.		
		Number of channels . .	1 service conversation and 12 telephone channels 4 kHz, or 1 such conversation and 15 channels, 3 kHz.		
		Frequency control . . .	Quartz.		
	c)	Calling	According to the method in use on the particular channel concerned.		
	d)	Aerials	Directional pattern.		
		H.F. range	41 ÷ 68 MHz.		
		Field unit (Champ unitaire).			
		Saving of aerial per field 17 (Gain d'antenne par champ 17).			
1.4.3.1.3.	*a)*	Source of power. . . .	Local supply; In case of failure : standby equipment.		
	b)	Characteristics	50 W.	250 W.	1.5 kW.
		Consumption	750 VA.	2 kVA.	3.5 kVA.

1.4.3.2. *Spanish National Railways (R.E.N.F.E.).*

1.4.3.2.1.	*a)*	H.F. range	Temporary : 2 ÷ 8 MHz divided into 2 bands : 2 ÷ 4.5 and 4.5 to 8 MHz.	Permanent : Frequencies fixed between 3.5 and 14 MHz.
		B.F. range		300-2 700 Hz.

	b)	Emittive power	20 W. in the case of 250 W. non-modulated carrier wave.	
		Modulation	Amplitude.	
		System	Simplex.	Duplex.
	c)	Calling	Communication is arranged to take place at certain prescribed hours.	Modulation of the carrier waves by two tone frequencies.
	d)	Speech transmission . .	Micro-telephone.	Micro-telephone.
	e)	Aerials	L. form, total length 3/4λ.	Horizontal dipole λ/2.
1.4.3.2.2.		Where used	In stations.	One transmitter, 2 receivers, a teleprinter calling selector and power supply located in a room in the station.
1.4.3.2.3.		Source of power. . . .	Converter from 12 V to 275 and 500 V or rectifier; 125/12 V, 3A, 125/175 V, 0.15A, 125/500 V, 0.15 A.	Local supply, A.C. 127 or 220 V, 50 C/sec. and a relief generating group of 3 k W.

1.4.3.3. *Italian State Railways (F.S.).*

These railways have provided the following information :

a) Installations connected with a regional division, or a power supply area :

American SRC 399.

Transmitter BC 610 (500 W-cw, 350 W — Ph, 2-18 MHz). Receivers BC 342 and BC 313.

b) Calabria and Sardinia :

American types,

Transmitter BC 375 (70 W-cw) 30 W — Ph, 1.5-12.5 MHz). Receivers BC 348.

c) Sicily :

American types.

Transmitter RCA and 4 336 H.

(350 W-cw, 250 W-Ph, 2-20 MHz). Receivers Bc 348.

d) Straits of Messina.

German modified « Michael » type (0.5 W — 500 — 600 MHz), two speech channels, 1 telegraph and 1 teleprinter channel.

2. Breakdowns and their prevention.

As regards the subdivisions of this section, the Administrations have provided the following replies :—

a) *Failures in the equipment. What steps are taken when the equipment or current supply break down.*

When a failure occurs, the first step taken is to try and localise it. In the case of fixed installations, the instruments necessary for this purpose form part, as a rule, of the equipment itself, or else are part of the apparatus with which the maintenance staff are provided. Movable equipment such as that carried on locomotives is withdrawn from service when a failure takes place. When the fault is found, the defective item (valve, etc.) is changed or any actual piece of apparatus (transmitter, receiver, etc.) replaced by a spare one. In stations where there is a large user of vehicles there is generally a spare one with transmitter and receiver, in order to avoid delays in carrying out the work as a consequence of failures.

Most often the various items of equipment are connected to the general wiring and cabling by plug connectors which facilitates interchangeability. The S. N. C. B. reports that this feature enables an item of equipment to be changed in two minutes by non-specialised staff. The D.B. follows the same practice in the case of failures, and when a defect is found to be serious, sends the apparatus for repair to its own central communications workshop.

As regards ordinary preventive maintenance reference may be made to Part I above. As complementary to this may be mentioned the measures taken by the Mediterranean-Niger Railway which inspects all installations on trains before they start on a journey to make sure everything is working correctly. Failures of the equipment supplying the current are always dealt with by the railway's own trained staff.

b) *Failures due to reception conditions. What steps are taken as regards failures caused by atmospheric disturbances or interference.*

Reference has already been made in Part I to the importance of failures produced by atmospheric conditions. When these give rise to an appreciable nuisance, « fading » phenomena can be partly got rid of by increasing the transmitting power.

c) *Failures due to external causes (outside transmitters, electric train operation, etc.).*

Where disturbances are experienced from other transmitters or other sources of interference, the D.B. reports the first step is to find out the cause and when this is not possible with the means at its disposal or when the disturbance is due to some installation not belonging to the railway, the Postal Department is requested to take the necessary measures.

The railway management deals with interference arising from its own installations and the Postal Department with any other.

* * *

The information contained in Part II may be summarised as follows :

Steps are taken to ensure that the construction of the wiring and cabling is such that failures are kept within the same limits as those applying to ordinary telecommunications equipment. Thus from the constructional point of view account has been taken everywhere, where conditions require it, of the importance of being able to withstand mechanical stresses, the risk of dirt accumulating, and the need to allow heat to escape freely.

All this, however, can only be regarded as a first step. Manufacturing engineers have still the task of studying with care every means of improving the apparatus. In railway working the reliability of the telecommunications plays an extremely important part in enabling traffic to be carried on without interruption, and only if that is fully realised can any extension of radio methods be counted on. From the electrical point of view account has been taken of experience gained in the last few years.

One thing to be noted is the increased development of frequency modulation which, compared with the amplitude form, offers a greater safeguard against interference, especially on electric lines. In addition, as far as information received allows of knowing, the apparatus is always fitted with quartz control led frequency oscillations, which ensure the frequency being kept very constant. The increasing use of radio installations for many different purposes has already led and will do so more still to an overlapping and congestion of frequencies in the ultra-short wave ranges. This has caused certain managements, for example the D.B., to lay down stricter delivery conditions for radio equipment and to reduce the interval between channels for frequency modulation from 100 to 50 kHz.

Future operating experience, which must be carefully collated, and technical developments will show the best waves to choose in the different fields of application on the railway. We can only refer readers to the different trials carried out by European and American Administrations, very briefly described in the first part of this present report, regarding the propagation of waves in tunnels, the results of which seem to show that in this field it is decimetric waves (ondes décimétriques) which are the most advantageous.

Owing to these facts, certain Administrations have already asked the Authorities controlling radio to reserve them frequencies in the decimetric and centimetric fields (domaines décimétriques et centimétriques). The other Administrations can only be recommended to take similar steps in their cases.

[621 .131 .2]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

16th SESSION (LONDON, 1954).

QUESTION 4.

Means and methods to improve the efficiency of steam locomotives :

a) increase of steam pressure,
b) types of grates,
c) superheating of the steam,
d) preheating of the feeding water,
e) feed water treatment,
etc.

REPORT

(Austria, Belgium and Colony, Bulgaria, Czechoslovakia, France and French Union, Germany, Greece, Hungary, Italy, Luxemburg, Netherlands, Poland, Portugal and Colonies, Rumania, Spain, Switzerland, Syria, Turkey and Yugoslavia),

by Dr. Ing. M. Diegoli,

Inspecteur en Chef Supérieur au Service du Matériel et de la Traction des Chemins de fer de l'Etat italien.

FOREWORD.

At the time of the Paris Congress in 1937, when this question was last dealt with, the steam locomotive had reached a full and brilliant condition of maturity, following a period of some ten years of intense development due to technical collaboration between Administrations, which had provided the means for achieving some very remarkable performances.

Seventeen years have passed since then; the position of the steam locomotive has now changed because of the progressive claims of other types of motive power and new economic and general conditions; its future is debatable and limited in time.

At the same time, it has seemed opportune to obtain the views of the various Administrations on this point, by extending the investigation to the present state of

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Note :

In the present Report, certain Administrations have been indicated by abbreviations as follows :

— D.B. : German Federal Railways;
— F.S. : Italian State Railways;
— Ö.B.B. : Austrian Federal Railways;
— R.E.N.F.E. : Spanish National Railways;
— S.N.C.F. : French National Railways;
— S.N.C.B. : Belgian National Railways;
— S.N.C.Lux. : Luxemburg National Railways.

steam traction in relation to other types, and also forecasts of possible development during the next ten years.

Amongst the 63 Administrations to whom the questionnaire was addressed, only 12 have replied and it cannot be claimed that these replies all contributed positive information. This shows that many Administrations considered they had no information of interest to contribute.

A. Increased boiler pressure.

Boiler pressure considered preferable and reasons for this preference.

Table A summarises the characteristics (including the pressure) of the more modern and important steam locomotives used for train working on the various railways concerned.

In view of the importance of the question, however, it is worth while to add some considerations mentioned by the Administrations in question.

The *S.N.C.F.* which has amongst its most modern types 504 locomotives with a pressure of 20 hpz considers increased boiler pressure to be advantageous in order to increase the gross power and the efficiency of the drive. It is possible to increase the superheat temperature with the raising of the pressure to maintain the same relative degree of superheat; however, in view of the difficulties encountered in the use of superheat temperatures in excess of 400° C, a pressure of 18 hpz should be exceeded only where the locomotive is designed for very high speed running, experience having shown that in this case the surface friction is reduced.

These boilers, pressed at 20 hpz show goods results in service and suffer no defects other than those encountered in other boilers, the frequency and severity being comparable.

The *D.B.* has obtained the best results from boilers pressed at 16 atm. (15 hpz); they have in service 3 391 locomotives which operate at this pressure.

The *D.B.* consider the net efficiency of the boiler to be practically independent of the steam pressure, because if it is accepted that with equal superheat temperature, the superheater must provide a smaller amount of heat whilst the boiler pressure is increased, the reduction is at the same time so small that it cannot affect the final result.

Trials undertaken by the *D.B.* with boilers pressed at 25 and 20 kg/cm² (355 and 284 lbs per sq. inch) have not resulted in any important increase in the overall efficiency of the locomotive; on the contrary, they have given rise to numerous difficulties in service which have resulted in increased operated expenses.

Pressures were consequently reduced.

The reasons for this unsatisfactory behaviour are attributable more to the material from which the boilers were manufactured, rather than to the actual increase in pressure.

In fact, with the object of reducing weight, the *D.B.* used St. 47 K high tensile steel which did not fulfil expectations and showed itself to be unsuitable for welding.

Furthermore, St. 34 steel which gave good results in normal boilers, would have been too heavy in boilers of higher pressure.

Boilers pressed at 16 atm. by comparison with those of a lower pressure, do not require any special maintenance requirements; nor any special regulations regarding periodical overhaul.

The *R.E.N.F.E.* indicated a preference for boilers with a pressure of 16 or 17 atm., which are fitted to about 500 of its locomotives and this takes account of the fact that, even if higher pressures up to 20 kg/cm² give higher efficiency, the maintenance cost is increased by the frequency of periodical inspection and cost of repair, whilst the percentage of work is reduced.

Operation of 10 locomotives pressed at 20 kg/cm² has shown the necessity for numerous repairs, which led to the boiler pressure being reduced to 18 atm.

The *S.N.C.B.* whose locomotives have

ACTERI

200	a 2	»
700		—
.750		—
.500		—
.800		—
.025		—
4.32		—
4.600		—

pressures varying between 12 and 18 kg/cm² (170 and 256 lbs per sq. inch) is of the opinion that a pressure in excess of 16 kg/cm² (227 lbs per sq. inch) necessitates either the use of carbon steel plates of too great a thickness, which causes difficulties in mounting and steam tightness, or alternatively the use of alloy steels which are not free from defects.

The other railways included in the Table have not had occasion to undertake trials with engines pressed above 16 kg/cm².

For the construction of boilers pressed at 18 kg/cm² or above, therefore, special steels have been used, but only the *S.N.C.F.* has obtained good results in service. This Railway has generally used, since 1930, in boilers of 20 hpz, nickel steel (2 1/2 %) plates with the following characteristics :

elastic limit : 29 kg/mm² (18.41 t per sq. inch);
breaking load : 50 kg/mm² (31.75 t per sq. inch);
elongation : 20 %.

As this weldable steel is fairly sensitive to wide variations in temperature it is necessary to restrict the use of welding in repair work and to take special precautions.

The formula used to determine the thickness of plate is given by :

$$f = \frac{p \cdot D}{200 \cdot e}$$

where :

f = fatigue expressed in kg/mm²;
p = pressure in hpz;
D = diameter of boiler, and
e = thickness of plates in mm.

The value adopted for the fatigue f is about 9 kg/mm² (5.71 t per sq. inch) for the nickel steel plates (10 kg/mm² [6.34 t per sq. inch] with 2 mm [5/64″] wear).

The repair methods, maintenance, periodical examination and inspection regulations for these 20 hpz boilers are similar to those of other boilers except with regard to smoke tubes, which must be fitted new.

With regard to trials undertaken with special high pressure locomotives, the *S.N.C.F.* tested just before the last war the following types which were under construction or in the design stage at the time of the 1937 Congress :

— with Velox boiler, 20 hpz;
— turbine, pressure 25 hpz;
— multi-cylinder, pressure 60 hpz,

but none of these were returned to service after 1945. On the *D.B.* the widely known and unsatisfactory trials with special high pressure types have had no repercussions and no other Railway can be said to have achieved any practical progress in this direction.

For new boilers to be built, opinion is in general divided between 16 and 18 kg/cm².

In fact, the *D.B.* having regard to the fact that progress in the technique of welding offers certain favourable possibilities have in mind boilers of 18 kg/cm², constructed of ordinary St. 34 steel. The increase in weight resulting from the use of thicker plates would be offset by the reduction realised by extended use of welding in the construction of the boiler, frame and other parts.

The *R.E.N.F.E.* confirms its preference for pressures of 16 to 17 kg/cm² (227 to 241 lbs per sq. inch) and the figure of 16 kg/cm² is favoured by other Administrations, including those of the Colonies who consider that for their systems, it is not desirable to exceed this pressure.

The *S.N.C.F.* alone, although they have not sufficient experience to decide at what pressure increased maintenance cost overrides the advantages, consider that the adoption of a pressure of 20 hpz has not caused increased maintenance. Although there should not in future years be any new steam locomotives built on the S.N.C.F., because of the extension of electric traction, the question of size had caused them to consider a pressure of 22 hpz for the design of future powerful locomotives.

Summaries.

— Increasing boiler pressure is recognised as of practical value in improving the specific power and efficiency of the locomotive, but beyond a certain limit it causes increased maintenance costs and even increases the percentage of time out of service, which can seriously affect the financial position.

— It is the general opinion that this limit may be between 16 and 18 kg/cm² (227 and 256 lbs per sq. inch); the *S.N.C.F.* alone considers that it would be beneficial in the building of new powerful high speed locomotives to increase the boiler pressure to 22 hpz. This seems to be because this Administration has been able satisfactorily to solve the technical problems connected with the use of special steels.

B. Heating of the boiler.

Coal firing.

With manual firing, besides the traditional fixed grate, which is still very common, the shaker grate continues to be popular with several Administrations (Table B), when use is made of very cindery coal or with cinders which are more than usually combustible.

They are used by the *S.N.C.B.* for all train locomotives, on a large scale by the *R.E.N.F.E.* and by the *S.N.C.F.*, also to a moderate degree by the *F.S.* and other Administrations.

The *D.B.*, whilst recognising the shaker grate's facility for breaking and disturbing the clinkers has not obtained good results in tests with them because they melted and were subject to frequent jamming; for this reason they have discontinued their use. They therefore use, as does the *Ö.B.B.*, the *Portuguese Rys*, etc., fixed grates with a removable section.

With continuous mechanical stokers the use of the well known Hulson grates, with oscillating firebars which lead the air laterally to the same level of the bed of the fire to prevent the fire being broken up.

Grates are generally of ordinary cast iron or haematite cast iron with a low phosphorous content; the Hulson tubes are of refractory chrome castings; their life is very variable (see Table B) and depends mainly on the quality of coal used (see Table C) and the rates of combustion.

The free area of the grate for the passage of air varies from 17 to 23 % for the Hulson type to 30 to 38 % for shaker grates and 40 to 50 % for fixed grates.

The *D.B.*, which works on 43 %, considers that this proportion is particularly suitable for rich coal normally used for locomotives; at the same time in view of the recent tendency to take this coal away from the railways and use it for the production of coke, use will have to be made to a greater extent of gas coal and briquettes (smithy coal) with a lower calorific value and less favourable characteristics as regards ash and clinker, which may tend to cause difficulties in operation and have an adverse financial effect.

The *Ö.B.B.*, and the *F.S.* consider that their grates with a free area of 40 % are suitable for use with coal of a high or normal content of volatiles, adapting the heat flow as necessary. The *S.N.C.F.* considers that the steam locomotive must be capable of using lowest quality fuel but in order to give good service the coal must be classified in relation to the necessary rate of firing.

The ashboxes generally, in the case of hand firing, have frontal openings but there are some types with side ventilation; the *S.N.C.B.* has recorded that this arrangement greatly increases the life of firebars. In some recent locomotives, the *D.B.* has incorporated the ashbox in the actual frame of the locomotive separate from the boiler and the air is fed to the bottom of the grate by long narrow lateral slots.

The admission of air above the grate has been generally abandoned, apart from the *Ö.B.B.*, *S.N.C.Lux.* and the *Cambodian Railways.*

Brick arches are still considered an advantage in reducing the amount of combustible matter drawn off the fire and in improving the life of the firebox, particularly when mechanical stoking is used; in this case, according to the *S.N.C.F.*, their length should be at least 3/4 of that of the firebox with a radius of curvature varying according to the type of firebox, taking care that the free sections above the arch have a greater area than that provided by the smoke tube plate.

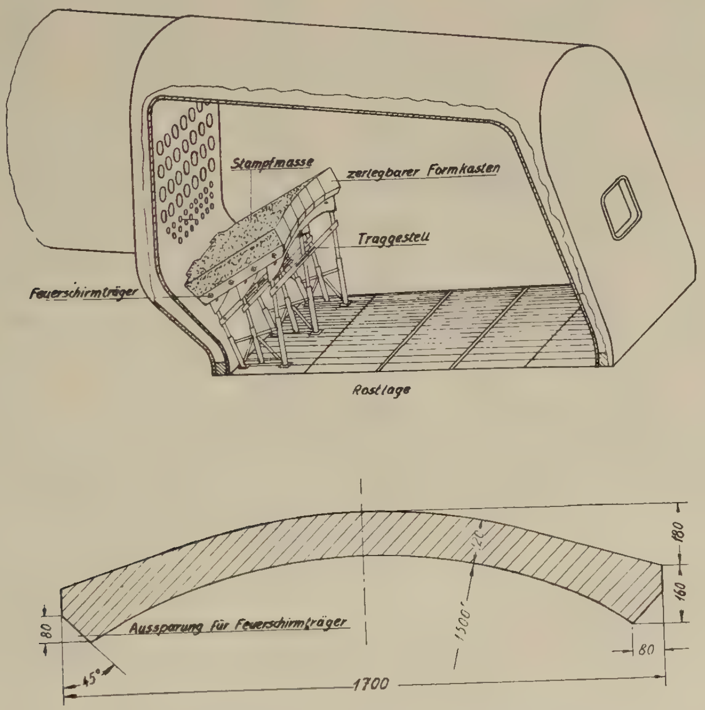

Fig. 1. — Construction of arch as pressed block (*D.B.*).

Explanation of German terms:

Stampfmasse = pressed block. — Zer. Formkasten = replaceable sections. — Traggestell = supports. — Feuerschirmträger = arch carrier. — Aussparung... träger = chamfer for carrier.

On the *S.N.C.F.*, the arches are made up either by arch bricks (large shapes) or by small bricks or by concrete (on trial); refractory bricks are of fireclay for normal use with coal but for use with heavy oil they must contain 42 % alumina.

The *D.B.* has standardised the dimensions of bricks which has allowed them to reduce the number of types to 7. Recently, with the object of achieving greater homogeneity, life and economy in construction, use has also been made of arch blocks, produced from fireclay sand (melting point 1 670° C) by means of a pneumatic press (Fig. 1). For the two types of construc-

TABLE B. — CHARACTER

ADMINISTRATION	*Type of locomotive*	*Type of grate*	*Total grate area* m^2	*Percentage of total grate area*	
				Free air passage area	*Ashpan a passage section*
S.N.C.F.	231 H	fixed	4.25	50	26.4
	141 P	Hulson	4.28	17	16.4
	141 R	Hulson	5.16	23	15.1
	241 A	fixed and rocking	4.43	50	20.6
	241 P	Hulson	5.05	18.7	17.1
	150 P	Hulson	3.54	18	25.5
	240 A.S.O.	rocking	3.76	38.5	18
D.B.	01	fixed firebars with removable grate	4.5	43	14.9
	03		3.9	43	15.6
	23		3.11	43	35.7
	41		4.09	41	19
	44		4.55	43	17.8
	50		3.9	43	20
S.N.C.B.	1	rocking grate	5.00		
	12	»	3.70		
	26	»	3.90		
	29	»	4.40	33.7	

TES AND ARCHES

aterials used for nstruction of grates	*Average life of grates*	*Materials used for arches*	*Average life of arches*	*Maximum grate area allowed for hand firing*	*Combustion rate* kg/m²/h
Rocking grates ave bars of F 1 ast iron Tubes f Hulson te are of efractory chrome ast iron (0.75 - 25% Cr.)	Very variable: depends particularly on quality of coal used	Best quality bricks for coal firing. Refractory bricks, 42% min. of alumina for oil firing. Concrete arches on trial.	Variable: any stage between 20 000 and 70 000 km	4.25 m²	Normal: 500; can reach 1 250
efractory ast iron	For fixed firebars 50 000 to 60 000 km For removable grates 25 000 to 40 000 km	Arch bricks (chamotte) or blocks moulded from refractory clay.	Very variable	4.5/5 m²	Normal: 300 to 500; maximum : 600 to 700
aematite ast iron		Refractory bricks for ordinary locomotives : 28 to 32% alumina; high speed passenger : locomotives 39 to 42% alumina.		5 m²	

TABLE B. — CHARACTER

ADMINISTRATION	*Type of locomotive*	*Type of grate*	*Total grate area* m^2	*Percentage of total grate area*	
				Free air passage area	*Ashpan a passage section*
F.S.	685	fixed	3.50	40	15.3
	691		4.30		13.3
	746		4.30		13.3
	740		2.80		16.6
Ö.B.B.	214	fixed grate	4.72	41.5	12.77
	729		3.55	42.5	13.5
R.E.N.F.E.	2700	fixed and dropping grates	5.30	48	19.2
	4600		5.00	48	20.8
	2400		5.25	48	15.8
Cambodian Rys	231500	fixed	2.86	35	15
	241500				
Bas-Congo-Katanga Ry .	700	rocking	4.04	32	12.5
	1700		4.80	25	18.6
S.N.C. Lux.	150	fixed	4.70	43	

ATES AND ARCHES *(continued)*.

Materials used for construction of grates	*Average life of grates*	*Materials used for arches*	*Average life of arches*	*Maximum grate area allowed for hand firing*	*Combustion rate* kg/m²/h
Cast iron	About 20 000 km	Refractory bricks	About 3 months	4.50 m²	Normal: 300 to 400; maximum : 500
Refractory cast iron	Minimum : two years	Refractory bricks (chamotte)	About 3 months with coal firing, a little longer with oil firing	5 m²	450 to 500
Rolled forged steel and cast iron for fixed grates; cast iron for dropper grates	17 000 km	Refractory bricks	3 months	5.50 m²	500
Cast iron	60 000 km	Refractory bricks 20-22 % of alumina			
Refractory cast iron		Refractory bricks 42 % of alumina		5 m²	
Haematite cast iron	18 to 24 months	According to S.N.C.F. specifications	3 months		

TABLE C. — **TYPES OF SOLID FUEL USED.**

ADMINISTRATION	*Type of fuel*	*Dimensions*	*Calorific value inferior*	*Volatil materials*	*Ash*
D.B.	75 % bituminous coal; remainder mainly gas coal	Sorted ~ 80 mm	7 600 ÷ 7 700	19 ÷ 28 %	5 ÷ 6 %
S.N.C.B.	*a)* fine coal, mixed with 60 % rich and 34 % semi-rich	Graded ~ 0/30	7 635	13 ÷ 31 %	6 ÷ 12 %
	b) screened		7 750	31 %	5 ÷ 6 %
	c) briquettes	10 kg	7 575	17 ÷ 18 %	9 ÷ 10 %
Ö.B.B.	Polish bituminous coal Ruhr rich coal		6 500 ÷ 6 700 7 127	34 % 30 %	5 ÷ 7 % 6 %
F.S.	German or English coal	20 ÷ 80 mm	7 600 ÷ 7 900	20 — 26 %	5 ÷ 7 %
R.E.N.F.E.	Briquettes Small coal Fine coal		7 502 7 575 7 450	22 % 32 % 23 %	14 % 11 % 14 %
Portuguese Rys	Mixture of : 50 % imported coal, 50 % portuguese anthracite compressed blocks		7 800 6 200	21 % 8.5 %	9 % 22 %
S.N.C. Lux.	Screened rich coal from different sources		7 400 — 7 700	20 ÷ 37 %	3 ÷ 8 %
Bas-Congo Ry.	Wood Luena (local) coal Wankie (Rhodesian) coal	20 ÷ 50 mm	4 000 ÷ 4 500 7 500	28 % 27 ÷ 31 %	28 % 10 ÷ 12 %
Cambodian Rys	Dipterocarpus wood	Logs ø 0.15 l. 0.40	3 500 ÷ 4 500		
Madagascar Rys	Forest wood, eucalyptus, mimosa, coal				

tion, brick or pressed block, a thickness of 120 mm (4 23/32") and a curvature of 1 500 mm (4' 11 1/16") radius are used.

Other Administrations also use arch bricks containing 20 to 40 % alumina.

The life of brick arches is shown to be very variable (Table B) according to the quality of material, the degree of heating in the kiln, the care taken in their construction, the dimensions and span between supports, and the service worked by the locomotive.

With regard to the limit of hand firing, the opinion of the *S.N.C.F.* is that a fireman can achieve a peak rate of 3 tons per hour, but that on an average one should not exceed 2 to 2.5 tons, which corresponds to grates of about 4.25 m² (45.74 sq. ft.).

The *D.B.* considers it is difficult to fix a limit in this respect, as it varies according to the class of locomotive, and type of service; in all cases, the limit generally corresponds to a grate area of 5 m² (53.82 sq. ft.) or a firing rate of 2 tons an hour.

This opinion is very largely agreed by the other Administrations.

Mechanical coal firing is extensively used on the S.N.C.F., which has up to the present fitted stokers to 1 125 modern train locomotives of 12 different types, which has in certain cases allowed them to increase the tonnage hauled by 25 %. With regard to the consumption of fuel, it is stated that if the rate of vaporisation falls (for example 7.07 in place of 7.26) the efficiency in cost per ton-km hauled increases following the better use of the engine power.

The emission of cinders is, however, increased; it is therefore necessary to use suitable fuel; 30 to 40 % of volatiles and 4 to 5 % of non-combustible ash.

The *S.N.C.F.* has 49 tenders equipped with coal-pushers for bringing the fuel within reach of the fireman; the actual firing is done manually. The use of this procedure has not been extended.

The *D.B.* which, since 1950, has fitted 15 locomotives of two different types with automatic stokers using Hulson grates, report in regard to this that it is extremely important to choose the right type of grate and fuel. The use of rich coal, screened (18 ÷ 30 mm and 30 ÷ 50 mm) in a thin bed not more than 10 cm (about 4") has shown itself suitable; the increase in consumption is in the region of 6 to 10 % plus 4 % corresponding to the steam for operating the device.

Also equipped with a stoker are four locomotives, 5.30 m² (57.04 sq. ft.) grate area, of the *R.E.N.F.E.*, who note a certain increase in coal consumption which varies according to the type in use.

Finally, the *Bas-Congo-Katanga Co.* has ordered 12 locomotives, Garratt type, 5.34 m² (57.47 sq. ft.) grate area, fitted with stokers.

Firing with pulverised fuel has been given up everywhere.

Heavy oil firing.

The *S.N.C.F.* has fitted for heavy oil burning 638 locomotives of different types; for fast trains, for mixed traffic and also for shunting.

The *Portuguese Railways* have 183 oil-fired locomotives out of a total of 398 steam locomotives; they use, with good results, a type of burner where the pulverisation is done by inclined steam blasts, distributed around the fuel's exit, and often, to increase the effect, they reduce by about 15 % the section of the blast pipe. For fast train services, when combustion must reach up to 200 kg/m³/h, the vaporisation coefficients are about 11 kg of steam per kg of oil (10 300 cal/kg).

The *F.S.* have in service 70 oil-fired locomotives (American) for freight services and 8 for shunting with mixed fuel (oil and coal).

The *Ö.B.B.*, because of coal supply difficulties, equipped and kept in service until 1948, 192 locomotives for passenger and freight services, but the number has now been reduced to 34.

The *R.E.N.F.E.* at present possesses 25 oil-fired locomotives for passenger and freight services and they expect to increase this type of firing to 400 locomotives by 1955.

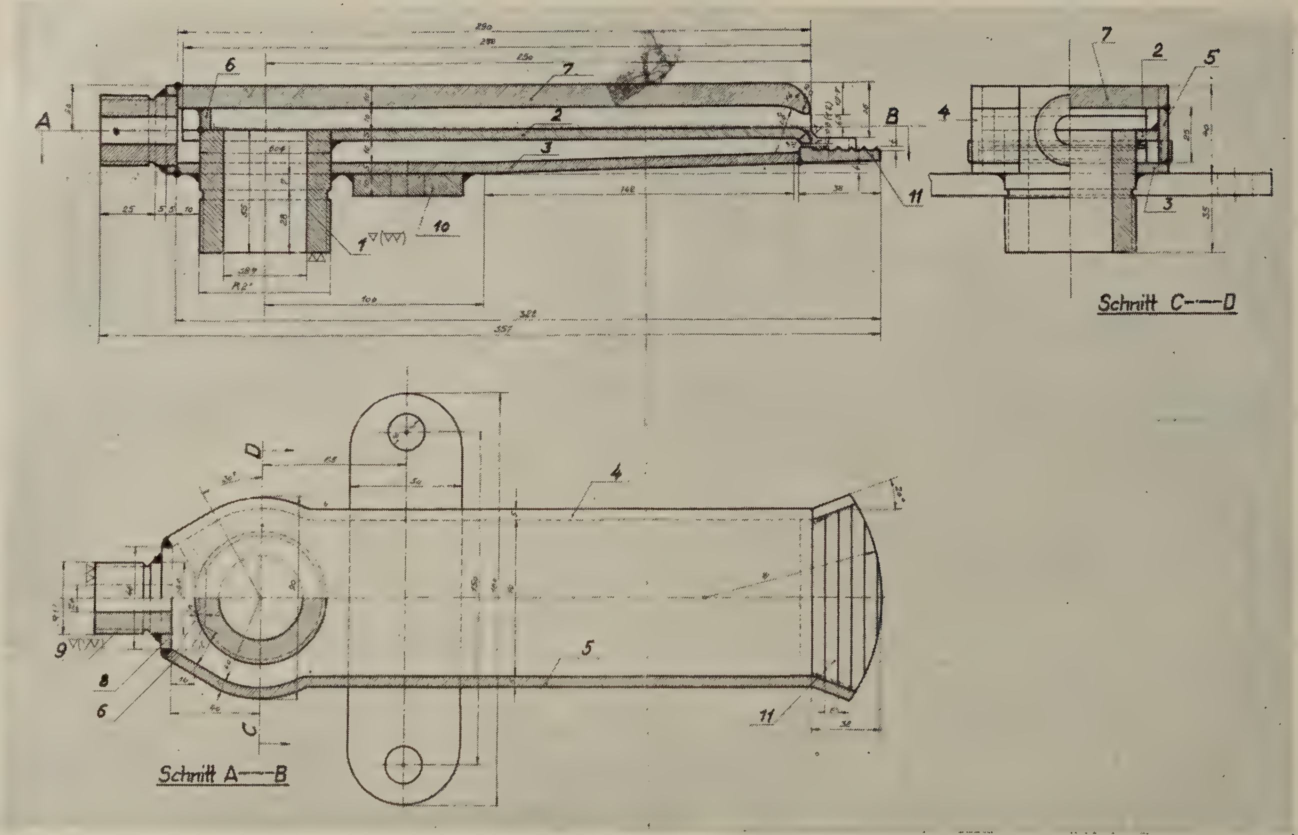

Fig. 2. — *Ö.B.B.* Flat type oil burner.

Schnitt = section.

On the *S.N.C.F.* the general characteristics of the fitting are : firebox with brick lining to the lower part and, in certain cases, with brick arch, burner located at the front with atomisation of the oil by steam jet, air intakes suitably distributed and oil pre-heated in the tender.

The average rate of evaporation is about 10 to 11 litres of water per kg of oil (12 litres for an hourly production of 3 t of steam and 8.5 litres for a production of 21 t); the hourly rate of oil burning may be as much as 300 kg per m^3 of firebox volume.

New types of burners now on trial have provided economies of about 10 %.

Complete combustion of oil must be obtained in the firebox to avoid heavy smoke, lower efficiency and, in certain circumstances, vibrations in the firebox; in addition combustion may be carried into the large tubes and so distort the superheater elements. For this reason the exhaust is restricted by about 20 % more than for coal and there is a better arrangement of the air intake, but it is also necessary to seek some means of improving the burners.

Trials have shown that a comparative rate is about 1.45 kg of coal to 1 kg of oil.

The *R.E.N.F.E.* has adopted an arrangement based on devices designed in North America, France and Portugal. The burners are of two types :

— American, in which the oil falls on a steam layer which projects it to the rear part of the firebox;

— Portuguese, which comprises semi-radial steam orifices.

Each of these two types has its advantages and a definite choice has not yet been made, the fittings only having been in use for a year; for the same reason there are not yet sufficient details available to provide a definite financial statement.

The *Ö.B.B.* in general also use in the front of the firebox a welded, flat type burner (fig. 2) which provides adjustment for consumptions of 1 500 to 200 kg/h. These have given satisfactory service and their price is moderate.

One characteristic fact is the admission of air across numerous short lengths of smoke tube, welded to the lower part of the firebox and embedded in the brickwork; this is designed to give better distribution and preheating of the burner air supply. The *Ö.B.B.* does not consider that with oil-firing it would be necessary to vary the rate because of the fact that the factors which operate, in addition to those which apply to coal firing, tend to compensate it; the average rate of evaporation is in the region of 10 kg of water per kg of oil.

Certain characteristics of the oil used by the above-mentioned Administrations are as follows :

	S.N.C.F.	*F.S.*	*R.E.N.F.E.*	*Ö.B.B.*	*Portuguese Rys.*
Calorific value, cal. . . .	—	10 500	9 800	10 000	10 400
Density	—	947	960 ÷ 970	—	950
Viscosity-Engler at 50° C.	14 to 60	10 to 14	20	—	12 to 20
Viscosity-Engler at 100° C.	—	—	—	2 to 3	2.3 to 2.9
Flashpoint	70° to 160° C.	—	80° C.	170 to 200° C.	140° C.
Water	1.5 %	1.5 %	1 %	0.4 to 1 %	—
Sulphur	4 %	—	2.5 %	—	—

Firing with other types of fuel.

The *Cambodian Railways* use only wood with a calorific value of 3 500 to 4 500 cal/kg, the *Bas-Congo* and *Madagascar Railways* use either wood or coal. For wood-burning the most suitable free grate area is 30-35 %.

The *R.E.N.F.E.* having tried agglomerate containing a percentage of anthracite pea-coal, which resulted in a marked increase in consumption, consider that without preliminary modification of the firebox, it is not possible to use any fuel other than coal.

The *F.S.*, for some time used for normal services freight locomotives fired with lignite (4 000-4 500 cal/kg) with fairly satisfactory results, using shaker grates with an area for the fire passage of air of about 46 %.

They have also carried out trials on fast and express passenger services using, without modification to the fixed grate or the blast pipe, semi-coke (est. calorific value 7 500 cal/kg, 9.5 % friable ash) arising from partial distillation of English or German small coal. Provided that the volatile content was not below 6-7 %, this fuel provided the same service as with normal coal (the grate still remaining clean) with a water/coal proportion of 6 instead of 7. It was, however, very bulky for the tender and the arrangement was found, at that time at least, to have no overall financial advantage.

At the present time the *F.S.*, purely for the purpose of technical and economic investigation, still have on trial several locomotives in freight services fired by methane (CH_4).

In the firebox, the grate is replaced by a series of premixing burners; air enters through the ash-pan in the usual way. The burners are fed at low pressure (0.1 ÷ 0.6 kg/cm^2) by means of a decompression group fitted on the tender and connected as desired to cylinders of 180 kg/cm^2 (3 982 lbs. per sq. inch) also placed on the tender to give the locomotive the necessary freedom in the depot, or by strong flexible tubes to the general supply, at present comprising a wagon of cylinders behind the locomotive. The behaviour of the boiler has been smooth and certain; maximum hourly evaporation is at least equal to that obtained by coal and can be varied rapidly and at will; it has special advantages when stopping or stabling and for fire-lighting.

With gas of a lower calorific value than 8 300 cal/m^3, an evaporation is obtained at 2/3 maximum application of 8.3 kg of water per m^3 of methane, 7.3 kg with normal coal.

The financial result in suitable conditions would be favourable; the practicability of using this system in present services remains limited, however, to locomotives for passenger and freight services on secondary lines in places where there is already a methane distribution system (pressure ∼ 50 kg/cm^2), which allows easy re-fuelling every 100-120 km without resorting to expensive fixed installations.

Summaries.

— Rocking grates are still widely used by railways who burn coal with a high proportion of cinder.

— The use of coal pushers is not being extended.

— The mechanical stoker has been considerably developed, but as it usually entails increased fuel consumption, its use should be restricted to locomotives with a grate area of 4.5 to 5 m^2 (48.34 to 53.82 sq ft.) and high combustion rates.

— Firing with pulverised coal has been discontinued.

— Oil firing has reached a high degree of efficiency and fairly wide adoption which seems to be continuing; its economic advantage can however vary in accordance with the difference in the market prices of oil and coal.

C. Superheating of steam.

Production of superheated steam.

In modern locomotives with boiler pressures of 16 to 18 kg/cm^2 (227.57 to 256.02 lbs per sq. inch) the temperature of the superheated steam is between 380 and 400° C and may even be somewhat higher. The *S.N.C.F.* reach 425° C in their 20 hpz boilers.

A limit of about 400° C is at present thought to be the most practical; it however requires the provision of adequate lubricating oil and improved castings for piston segments. Any advantage there is in reaching higher values to increase thermo-dynamic efficiency adds to the chance of burning the rear bends of the superheater elements, which the *D.B.* and the *Ö.B.B.* are trying to prevent by a thick chroming of the tube elbows.

Another interesting measure in this respect adopted by the *D.B.* on the series 23 locomotives is the multi-valve regulator (fig. 3) located behind the superheater and not in the saturated steam circuit; by this means it is hoped to prevent, when the regulator is closed, excessive temperatures in the superheater elements which remain filled with steam for auxiliary services and is also beneficial for the efficiency of the latter.

With regard to the superheater elements, the types used are in all cases already well known; amongst others the Schmidt type is very widely used; Houlet and 5 P 4 types are used by the *S.N.C.F.* for express locomotives.

The most suitable distance for the rear bends of the elements in relation to the firebox tube plate (normal type) is about 400 mm (1′ 3 3/4″).

The drop in steam pressure between the boiler and the steam ports does not, on engines with well designed steam circuits, in the opinion of the *S.N.C.F.*, exceed 500 g/cm^2 (7.11 lbs per sq. inch) at normal rates.

The diagram in figure 4 shows the drop in pressure noted by the *Ö.B.B.* on their

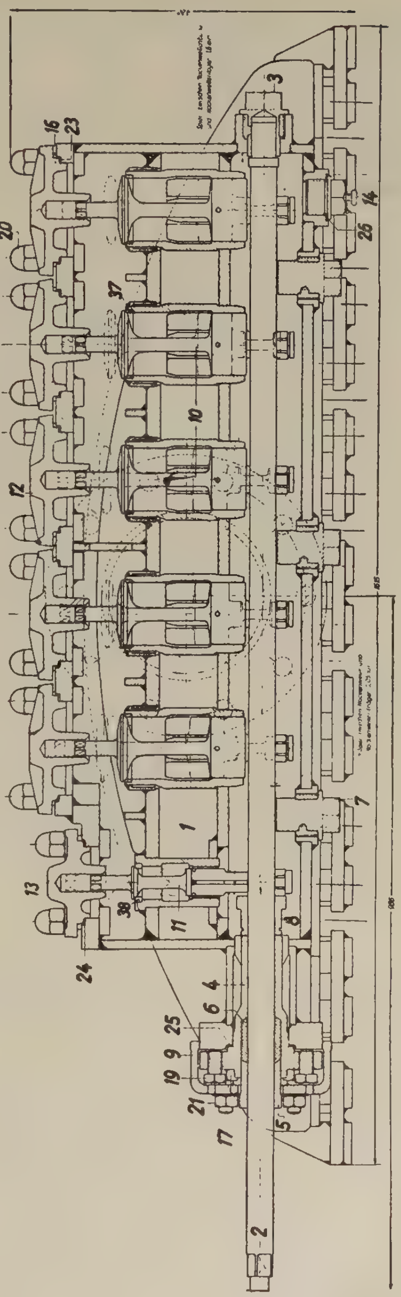

Fig. 3. — *D.B.* Multi-valve superheat regulator.

series 214 locomotives, related to the speed of travel for varying cutt-offs.

The *D.B.* has made an analysis of the pressure drop (Table D) in relation to the various parts concerned on two locomotives, one fitted with a normal regulator and the other with the multi-valve regulator already mentioned.

heat, the rear bends must be replaced more frequently than with other types, but it is exceptional for this to require attention in the depot.

In general, there are no special fittings to prevent water being drawn from the boiler into the superheater; the *S.N.C.F.* has obtained satisfactory results with a channel having a longitudinal slot connecting to the boiler as high as possible; the *Luxemburg Railways* use a dome with a perforated plate. The *D.B.* is considering the design of a suitable fitting.

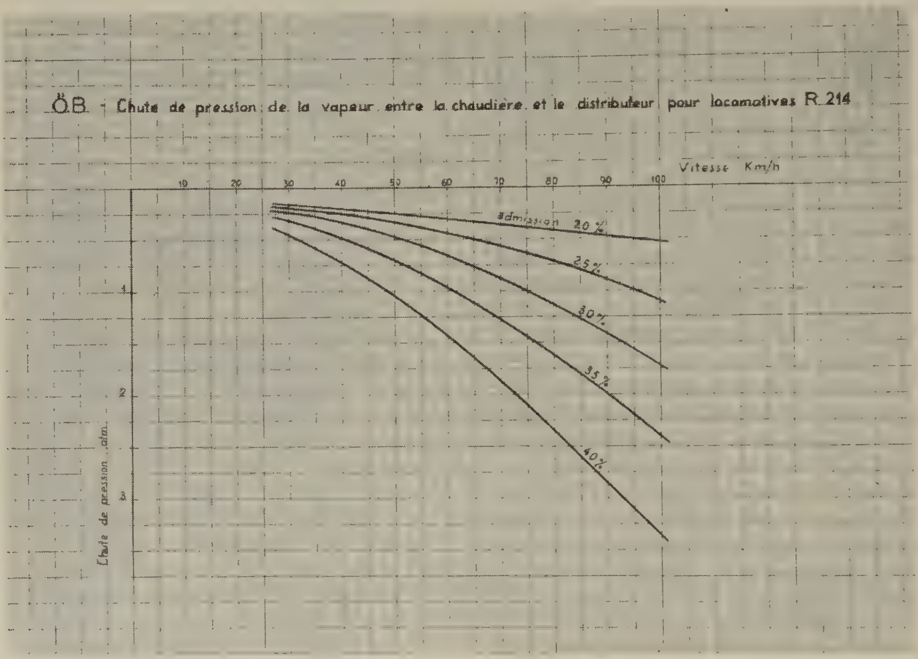

Fig. 4. — *Ö.B.B.* Steam pressure drop.

Explanation of French terms:

Chute de pression = pressure drop. — Admission = cut-off. — Vitesse = speed. — Chute de pression de la vapeur entre la chaudière et le distributeur, pour locomotive R 214 = pressure drop between boiler and steam chest, R 214 locomotive.

Superheater flue tubes have external diameters of 130 to 150 mm (5 1/8″ to 5 23/32″), the section for the passage of combustion gases through these tubes represents on recent locomotives of the *S.N.C.F.* 48-57 % of the whole of the tube area.

It is normally desirable that the superheater elements should need very little shed attention; defective joints (leaks) are unusual. On locomotives with high super-

Intermediate superheating of compound locomotives is not used. The *S.N.C.F.* has carried out trials in this respect which have shown that the most simple and effective method would be to surround the H.P.

TABLE D. — ANALYSIS OF PRESSURE DROPS BETWEEN BOILER AND VALVE CHEST

	Class 23 locomotive (multi-valve regulator behind superheater)		*Class 50 locomotive (normal regulator)*	
Pressure drop in :	*Evaporation 6 t/h*	*Evaporation 11 t/h*	*Evaporation 6 t/h*	*Evaporation 11 t/h*
Auxiliary valve	0.22 *atm*	0.29	—	—
Elements.	0.23	0.46	0.26	0.47
Regulator	0.025	0.25	0.17	0.32
Ports	0.025	0.15	0.02	0.29
Total drop	0.50	1.15	0.45	1.08

cylinders only with a steam envelope and superheat the steam only before admission to the L.P. cylinders.

Lubrication of valves and pistons.

Table E gives the main oil specifications adopted by the various Administrations for lubrication of superheated engines.

These oils, used within suitable ranges of temperature, give generally good results in service.

All modern and recently-rebuilt locomotives are provided with mechanical lubricators, fitted at the end of the supply tubes, near the part to be lubricated, with claps or non-return valves.

Oil consumptions are given in Table F.

Valve and piston segmented rings.

The particulars supplied on this subject are summarised in Table G.

It is particularly interesting to note that on the *S.N.C.F.* the packing used for the pistons of recent locomotives have been American « Koppers » segments (fig. 5) in special cast alloy and bronze which gives a high surface finish to the cylinders; each of the segments is made up of six radial parts held against the cylinder wall by a spring. They are generally used in threes on the H.P. piston and in pairs on the L.P. piston, the cast alloy segment being on the outer side.

The composition and characteristics of the alloy and bronze used for « Kopper » segments are as follows :

Special alloy :

Graphite carbon	2.8
Combined carbon	0.35
Silicon	2.1
Manganese	0.5
Phosphorus	0.4
Sulphur	0.05
Chrome	0.3
Nickel	1.1
Titanium	0.05

Bend test (on test piece 35 × 10 × 6 mm) between 30 mm spaced bearings : breaking load : 490 kg.
Deflection to fracture : 0.33 mm.
Shear test : 30-31.5 kg/mm².
Hardness test (10 mm ball with 3 t load) : 219-222.

TABLE E — CYLINDER

ADMINISTRATION	*Type of oil*	*Usage*	*Content of*		*Density*		*Co geal poi*
			Asphalt %	*Ash %*	*At a temperature of*	*Value point*	
S.N.C.F.	C. 3	Steam superheated 350° C.	0.5	0.10	—	—	+
	C. 4	Steam superheated 350 ÷ 370° C.	0.5	0.10	—	—	+
	Vx4	Steam with very high superheat	0.04	nil	—	—	+
S.N.C.B.	—	Superheated < 350° C.	nil	0.02	15°	0.895	+ 3°
	—	Superheated > 350° C.	»	0.04	15°	0.903	0° (
D.B.	05 201	Superheated < 340° C.	0.05	0.02	15°	< 0.950	— 10
	05 202	Superheated > 340° C.	0.05	0.02	15°	>0.935	— 10
Ö.B.B.	—	—	0.025	—	—	0.905	—
	—	—	0.05	—	—	0.910	—
R.E.N.F.E.	*H-7*	Superheated steam	0.5	0.1	15°	0.920 ÷ 0.970	
C.F.R. Cambodge . .	—	—	—	—	—	0.905	—
F.S.	B	Superheated steam	nil	—	15°	0.920	+ 0

CTERISTICS

Inflammability			*Viscosity (Centistok or Engler)*				*Acidity*	*Saponification index or saponifiable content*
ratus ed	*Flash point*	*Combustion point*	*at 50*	*at 100*	*at 150*	*at 200*		
ort	300°	—	—	54 ÷ 40	—	6	0.3	0.3
»	308°	—	—	69 ÷ 54	—	7	0.3	0.3
»	290°	—	—	40	—	5.1	0.28	9
M	298°	364°	328	41.8	12.2	—	0.15	3.3
»	310°	375°	460	53	14.8	—	0.10	nil
egel	< 290°	—	—	4 ÷ 8 E	—	—	—	
»	> 320°	—	—	5 ÷ 8 E	—	—	—	
—	—	344°	—	8.3÷9.2E	—	—	—	
—	—	324°	—	5.8 E				
pen ase	300°	340°	80 E	5 ÷ 7 E	—	—	0.2	
—	—	363°	—	7.1 E	—	—	—	
eland	330°	—	—	7 E	—	—	0.2	nil

TABLE F. — CONSUMPTION OF CYLINDER OIL IN RELATION TO MILEAGE.

ADMINISTRATION	*Type of locomotive*	*Type of lubrication*	*Kilometric consumption gr/km*	*Services worked*
S.N.C.F.	240 P 241 P 141 P 141 R 150 P	mechanical » » » »	13.5 12.5 12.5 12 12.5	passenger » » » freight
D.B.	01^{10} 03^{10} 23 41 44 50 - 52	mechanical » » » » »	24.3 23.5 24 20.5 25.8 22	passenger » » » freight »
S.N.C.B.	1 7 29 26	mechanical » » »	20 14 11.5 12.5	passenger » mixed freight
Ö.B.B.			8 6.5 4.5-5.5	passenger freight freight and shunting
F.S.	685 691 740 746	mechanical » » »	8 9.5 7 9.5	passenger » freight passenger
Cambodian Rys.	—	—	9	—

Special bronze :

Copper	80.5
Tin	13.0
Lead	5.0
Nickel	1.3
Zinc	0.25
Iron	Nil

Tensile test :

— breaking load : 22.6 kg/mm²;
— elastic limit : about 17 kg/mm²;
— elongation : 4 %;
— reduction in area : 4 %.

ADMINIS-TRATION	*Type of segments*	*No. of segments per piston*	*Tail-rods*	*Materials used*	*Life*	*Remarks*
S.N.C.F.	Koppers	3 double H.P. 2 double L.P.	no	special bronze and cast iron	2 full periods (280 000 km)	Used on recent locomotives
D.B.	ordinary	5 narrow, or 3 large	yes no	perlitic cast iron »	70 to 90 000 km	
Ö.B.B.	ordinary	3 (8 mm wide).	usually yes	perlitic cast iron	60 000 km	
S.N.C.B.	special	2 double	no	special bronze and cast iron	120 000 km	Segments of special type are used on recent locomotives of American origin type 29.
	normal	generally 3	yes	perlitic cast iron	60 to 70 000 km	
R.E.N.F.E.	normal	3		cast iron	10 000 km	
F.S.	normal	2 or 3	yes	cast iron	60 000 km	
Bas-Congo Ry.	Hunt-Spiller	2 double		special bronze and cast iron	150 000 km	
Cambodian Rys.	ordinary	4	yes	cast iron	50 000 km	
Madagascar Rys. . . .	ordinary	3	only for locomotives 72 tonnes	cast iron	60 000 km	

TABLE H. — TYPES OF PREHEATERS USED.

			S.N.C.F.	*S.N.C.B.*	*D.B.*	*F.S.*	*Ö.B.B.*	*R.E.N.F.E.*	*Portuguese Rys*	*S.N.C. Luxemburg*	*Cambodian Rys*
Exhaust steam		Exhaust steam injector	—	411	—	230	43	3	4	—	—
		Knorr surface	—	—	9 254	—	—	—	52	—	—
	mixers	ACFI	2 362	287	—	—	—	1 026	6	60	12
		Worthington	1 364	284	—	—	—		11	—	—
		Dabeg	443	—	—	—	—		—	—	—
		Henschel MVR	—	—	40	—	—	—	—	—	—
		Henschel MVT	—	—	2	—	—	—	—	—	—
		Heinl	—	—	2	—	62	—	—	—	—
Combustion gas		Franco-Crosti	—	—	2 (1)	125	—	—	—	—	—
Total number of locomotives fitted			4 169	982	9 300	355	105	1 029	73	60	12
No. of locomotives on the railway			6 506	1 696	10 300(2)	3 800	970	2 987	398	131 (3)	24

(1) Gr. 42 locomotive; also scheme for the conversion of two gr. 52 locomotives.

(2) Included 1 500 used for shunting.

(3) Included 45 used for shunting.

On the *S.N.C.B.* the recent series 29 locomotives of American origin are fitted with special segments (fig. 6) similar to the « Koppers » used on the *S.N.C.F.*, in phosphor-bronze (copper : 88.7 %; tin : 11 %; phosphorus : 0.3 %) and soft perlitic cast iron; segments of the same type (Hunt-Spiller) have also been used since 1950 by the *Bas-Congo Railway*.

All the special types of segments mentioned above have large bearing surfaces, which eliminate the need for piston tail-rods; the machining process described by the *S.N.C.B.* is very simple; the segment is dressed, cut and finished to the cylinder diameter.

The life of these special segments compared with ordinary segments is about double on the *S.N.C.B.* and on the *S.N.C.F.* it is doubled on the L.P. and quadrupled on the H.P. pistons.

The *D.B.* have for several years used pistons with 5 narrow segments 8 mm (fig. 7), which give good steam-tightness.

Valve and piston packings.

In recent highly superheated locomotives, use is made generally of packings comprising multiple metallic segments, designed not to hold the rod but solely to ensure steamtightness and at the same time allow some degree of movement to the rods.

This packing is made up of separate elements, taking up play automatically by spring loading, and gives perfect steamtightness, reduced wear on the rod, less lubrication and economy in maintenance. Soft perlitic cast iron and lead-bronze are the metals generally used for these segments.

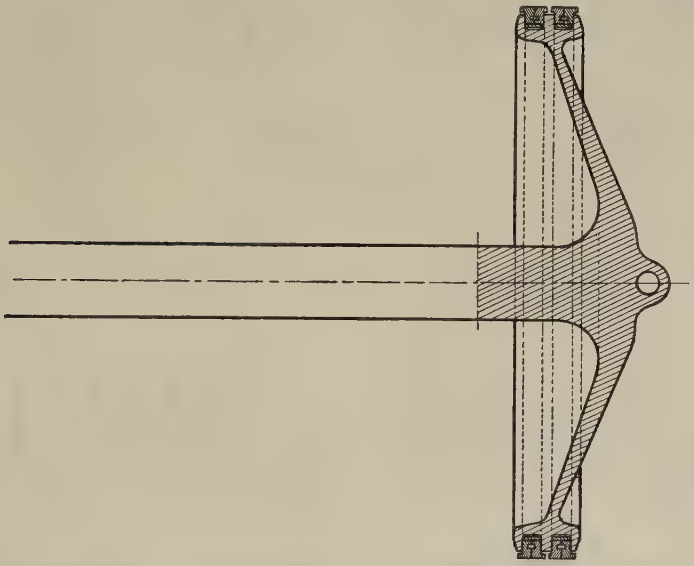

Fig. 5. — *S.N.C.F.* Kopper segmental piston rings.

Summaries.

— Superheating of steam has not noticeably varied during recent years and a temperature limit of about 400° C for locomotives with a boiler pressure of 16-18 kg/cm^2 (227-256 lbs per sq inch) can still be considered valid.

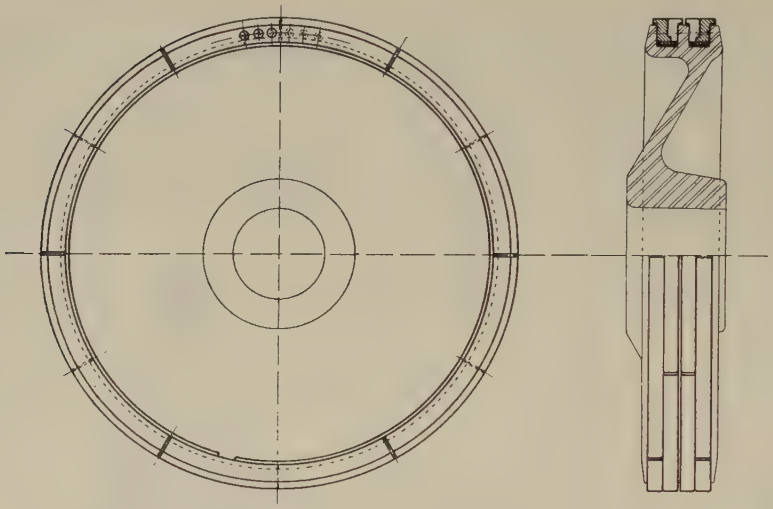

Fig. 6. — *S.N.C.B.* Special American type segments.

— By comparison with the reports to the 1937 Paris Congress, there are no new features to be mentioned in this section; at the same time, certain measures designed to improve the life of superheater elements, the tightness and life of piston rings, are of special interest.

D. Preheating of feed water.

Table H shows that on the railways concerned, exhaust steam injectors generally have only a moderate application, whilst pump preheaters are widely used. Amongst the latter, surface preheaters still make up the majority but they are almost exclusively used on *D.B.* locomotives.

Combustion gas preheaters (Franco-Crosti type) are at present used fairly extensively by the *F.S.* and by the *D.B.* experimentally on several locomotives.

The increase in the ratio between the quantity of steam which passes through the superheater and the combustion gas, as a result of the use of an exhaust steam preheater must cause a drop in the superheat temperature. The *S.N.C.F.* considers that,

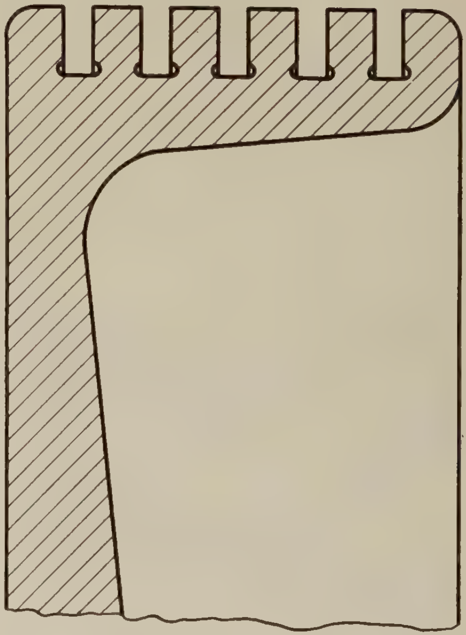

Fig. 7. — *D.B.* Piston with five segmental rings.

for this reason, the temperature falls from 400 to 385° C in a boiler pressed at 20 hpz which reduces slightly the economy effected by preheating because the consumption of steam per HP/hour is rather higher. On the other hand, preheating reduces the exhaust steam pressure, particularly when the engine is heavily worked; for example if it is taken that the counter-pressure was 500 g/cm² (7.11 lbs per sq. inch) it can fall to just over 400 g/cm² (5.68 lbs per sq. inch), equivalent in a high speed locomotive at 140 kilometres (87 miles)/h to a gain of approximately 60 HP; this supplementary benefit is in addition to that provided by the superheater as a primary function.

Preheaters of the type used by the *S.N.C.F.* give rise, for the same blast pipe area, to a slight loss of draught, about 1 % at low rates of combustion (250 kg/m²/h), but on the other hand, to a considerably increased draught at higher rates.

The *D.B.* on locomotives fitted with preheating adopts a reduced blast pipe area without exceeding the original counter-pressure values; it is not therefore possible to note in practice any reduction in the superheat temperature which would in any case be very small.

According to the *S.N.C.F.*, the percentage of exhaust steam used by the preheater is between 8 and 10 %; the consumptions in kg of live steam for the preheaters, taken during tests, were :

Hourly delivery of water to the boiler in t.	*5*	*10*	*15*
A.C.F.I., preheater — consumption	180 kg	295 kg	390 kg
Worthington preheater — consumption	200 kg	275 kg	—

Table I shows some test results obtained with a 141 P locomotive (20 hpz pressure) whilst the diagrams (fig. 8 and 9) show for a 141 R locomotive (15.5 hpz pressure) the differences comparing a Worthington mixed preheater and a normal injector from the point of view of boiler efficiency, coal consumption, cold water consumption, and superheat temperature.

On the *D.B.* the use of exhaust steam by the preheaters is in the region of 14 % and the temperature of the water delivered (quite apart from that in the tender) 90 to 97° for the surface and low pressure mixer types (in the Heinl preheater there are two stages and higher values are obtained). By increasing the period in service of surface preheaters, the places on which the steam impinges are found at shed examination to be oily and the water temperature drops to 80° C and even lower.

To operate preheaters, piston pumps are generally used, but in certain modern types turbo-pumps are also used; in connection with the latter, the *S.N.C.F.* points out the advantage of a non-pulsating steam consumption consequent upon the regular consumption of steam for operating the turbine which pumps the cold water. The *D.B.* which also uses the two types, reports that the turbo-pump has a higher steam consumption than the other type in particular at low loads, but that its consumption is in all cases independent of the length of service required from it, whilst piston pumps have specific consumption rates which are affected by the wear of parts, as can be seen from the following table :

Delivery in litres/min. with a pressure of 16 kg/cm²		50	100	150	200
KT 1 piston pump	new	3.5	2.5	2.0	1.8
	on withdrawal	15.5	7.3	4.0	3.8
T.P.B.B. 1 100 turbo-pump		5.6	3.4	2.6	2.2

TABLE I. — PREHEATING TEST RESULTS (S.N.C.F. SERIES 141 R LOCOMOTIVES).

Speed *km/h*	*Cut-off H.P.* *%*	*Power at rail* *H.P.*	*Steam temperature in blast pipe* *°C*	*Increase in temperature of water in preheater* *°C*	*Temperature of gas from* *large tubes* *°C*	*Temperature of gas from* *small tubes* *°C*
40	60	2 070	133	83	332	356
60	50	2 380	134	85	340	365
80	40	2 250	120	84	335	360
80	50	2 370	160	92	364	393
80	60	3 246	176	104	379	425
100	40	2 630	—	89	352	379
100	50	3 300	—	—	—	—
120	30	1 856	121	82	327	352

The *D.B.* however, at present prefer the piston pump, which has been more reliable in service. The general opinion is that preheaters are of robust assembly, they require little maintenance and give satisfaction. The *Ö.B.B.* estimate at 6 : 1 the ratio between the maintenance costs of the Heinl preheater and those of the exhaust steam injector; the *D.B.* consider that the annual maintenance costs of preheaters with piston pumps are about 5 % of the cost of fitting them.

Preheaters are generally considered to be instrumental in preserving the boiler. Those of the mixing type in particular, hold back considerable quantities of impurities, without however noticeably reducing incrustation, as the greater part of the scale is caused by concentration in evaporation. Some Administrations are seeking by the use of retardant re-actors to eliminate precipitation in the preheater where de-scaling is generally difficult.

The mixing preheater is more complicated and costs 50 % more than the surface type but it is more effective and thus generally preferred; the *D.B.* and *Ö.B.B.* in particular consider that this type could well be improved by the addition of a hot water reservoir for feeding the boiler when the regulator is closed, in view of the fact that the efficiency of a preheater is appreciably reduced when a train has numerous halts.

The reheating of feed water by gases has been effected in a very interesting manner in the Franco-Crosti boiler, the principle of which is to separate the tube plate into two parts, one for evaporation and superheating, the other providing a smaller area for passage of gas already cooled which provides a reheating of the feed water. This reheater functions at the same pressure as the boiler; it is fed by a piston-type live steam pump and because of its considerable volume, it is also designed to feed the boiler with hot water when the regulator is closed.

Figure 10 is a diagram of the Franco-Crosti boiler and a corresponding diagram of the temperatures of the combustion gases compiled by the *D.B.* following tests with a series 42 locomotive.

The *F.S.* fitted 10 locomotives with this system about ten years ago and have more recently converted 125 locomotives, of which 90 are of the class 743 medium powered type for freight working.

Economy in fuel by the use of feed water heaters compared with ordinary injectors

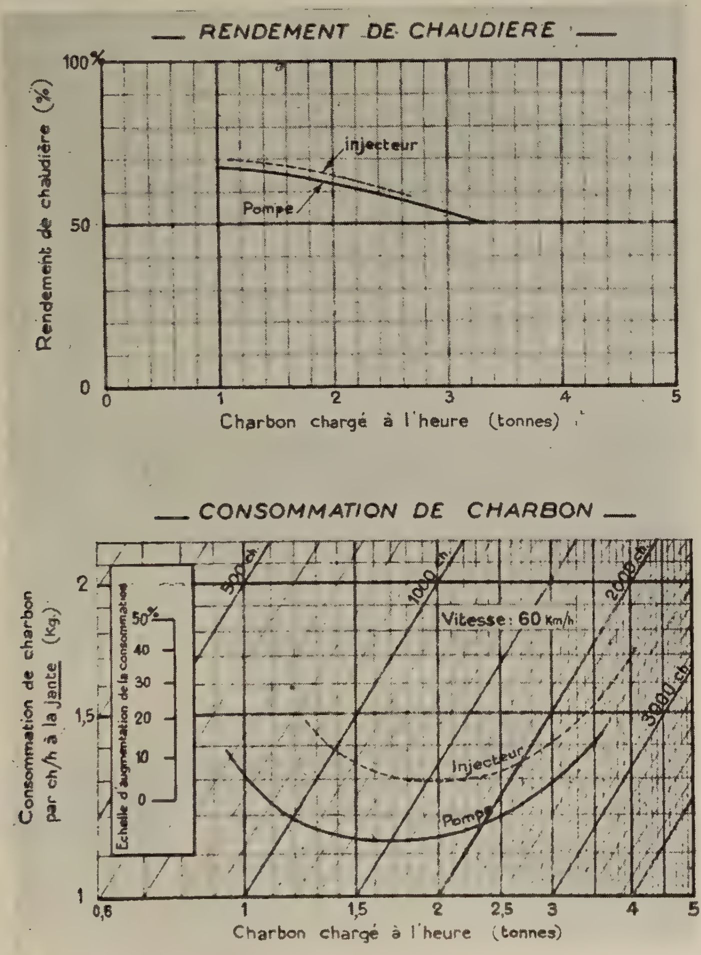

Fig. 8. — *S.N.C.F.* 141 R locomotive.
Comparison of Worthington preheater and normal injector.

Explanation of French terms:
Rendement de chaudière = boiler efficiency. — Charbon... heure (t) = coal fired per hour (t). — Consommation de charbon = coal consumption. — Echelle d'augmentation = rate of increased consumption.

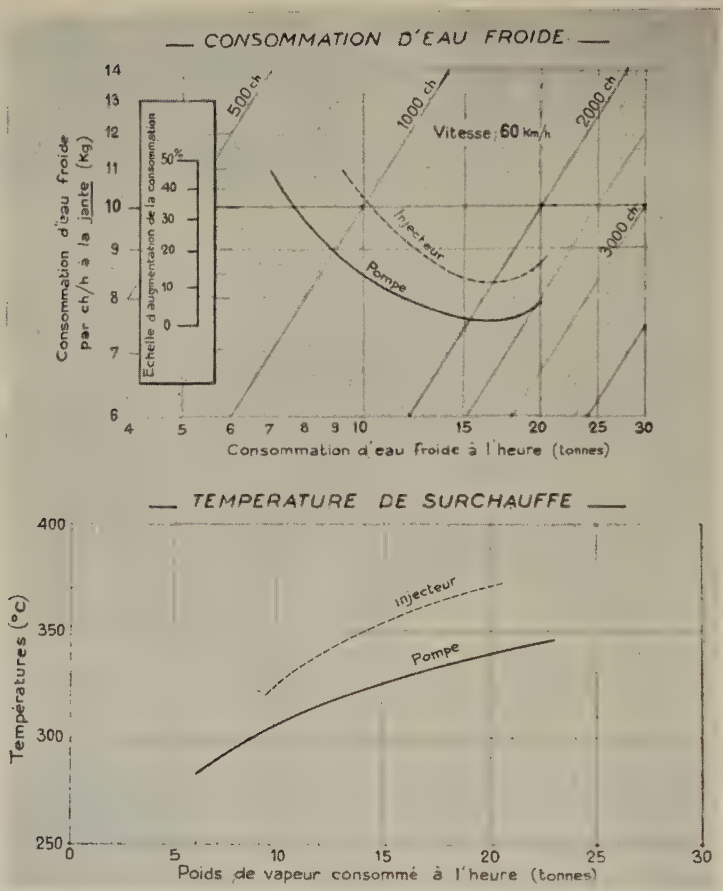

Fig. 9. — *S.N.C.F.* 141 R locomotive.
Comparison of Worthington preheater and normal injector.

Explanation of French terms:

Consommation d'eau froide par ch/h à la jante (kg) = consumption of cold water per HP/h at rail (kg). — Température de surchauffe = superheat temperature. — Poids de vapeur consommé à l'heure (t) = weight of steam consumed per hour (t).

is evaluated by the differents Administrations as follows :

S.N.C.F. — Worthington mixer preheater tested at the Vitry plant on a 141-R locomotive :

for 2 000 HP	coal consumption, saving . .	12.5 %
	cold water consumption, saving	9.5 %

R.E.N.F.E. — Mixer reheaters of various kinds :

on accelerated passenger and freight services	coal consumption, saving . .	10 %
	water consumption, saving . .	11 %
on freight services with frequent stops	coal consumption, saving . .	7 %
	water consumption, saving . .	7.5 %

Ö.B.B. — Heinl mixer preheater :

fast passenger services	saving of coal	12 %
ordinary passenger services	saving of coal	10 %

Cambodian Railways. — ACFI mixer preheaters :

mixed traffic and freight with fairly widely spaced stops	coal saving	8 %
	water saving	9 %

D.B. — In service :

surface preheaters	saving of coal	4 %
Henschel mixer preheaters	saving of coal	7.76 %
Heinl mixer preheaters	saving of coal	10 %
Franco-Crosti gas preheaters . . .	saving of coal	15 %

The latter results are not considered final as tests are still proceeding in a more suitable type of service, with heavy freight trains.

F.S. — Franco-Crosti preheater, with 743 class locomotives :

freight services with good working conditions	coal saving	20 %

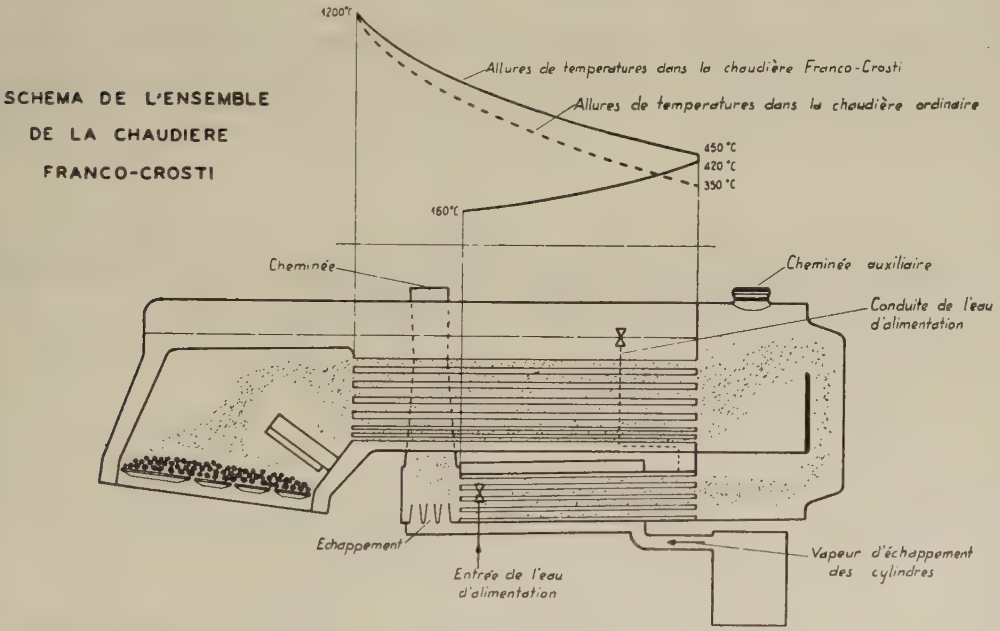
SCHEMA DE L'ENSEMBLE
DE LA CHAUDIERE
FRANCO-CROSTI
1200°C
Allures de temperatures dans la chaudière Franco-Crosti
Allures de temperatures dans la chaudière ordinaire
450 °C
420 °C
350 °C
160°C
Cheminée
Cheminée auxiliaire
Conduite de l'eau d'alimentation
Echappement
Entrée de l'eau d'alimentation
Vapeur d'échappement des cylindres

Fig. 10. — Diagram of Franco-Crosti boiler.

Explanation of French terms :

Allures de températures dans la chaudière Franco-Crosti = temperature range in Franco-Crosti boiler. — Allures de températures dans la chaudière ordinaire = temperature range in ordinary boiler. — Cheminée = chimney. — Cheminée auxiliaire = auxiliary chimney. — Conduite de l'eau d'alimentation = feed water pipe. — Echappement = exhaust. — Entrée de l'eau d'alimentation = feed water intake. — Vapeur d'échappement des cylindres = exhaust steam from cylinders.

TABLE L. —

ADMINISTRATION	*Physical lineside treatment*	*Chemical treatment outside the boiler*
S.N.C.F.	Nil	Lime-soda softening sometimes before « Tia »
D.B.	Nil	Nil
Ö.B.B.	Trials with « Cepi » magneto-static and ultrasonic fittings, without satisfactory results	Done in lime-soda plant
S.N.C.B.	Nil	About 50 % of the water is tre cold in lime-soda or saturation p
F.S.	Trials with magnetic « Cepi » electronic and mercury fittings, without satisfactory results	Lime-soda plants have been aband
R.E.N.F.E.	« Nise » and « Poliradia » processes used	Nil
S.N.C. Lux.	Trials made	Nil
Portuguese Rys	Nil	Nil

R TREATMENT.

hemical treatment inside the boiler	*Introduction of reagent*	*Type of reagent*	*Blow-down*
ral internal treatment A »	Reagents are introduced in the tender whenever water is taken, proportional to the quantity of water taken, by automatic doser; this is preferred to manual dosing. No fitting for direct introduction to boiler	According to the kind of water: tannin extracts, polyamide, caustic soda or alkaline salts	Remotely controlled valve either steam or air-operated. Extraction rate about 5 %
nical treatment	By hand into the tender. Where there are separate tanks the reagent would be put in the tank to avoid sludge in the boiler	According to the kind of water; preferably soda softening with anti-primer	By valves, partly compressed air operated
systems : i-sodic phosphate; TIA »; Aquasan » and Tartrizite » reagents; Nalco » reagent	Trisodic phosphate directly into the boiler after wash-out; other systems provide for introduction into the tender	Those already mentioned	By means of : — Friedmann fitting; — Gestra valve, air or hand operated; — « TIA » valves, steam operated
age water treated minarily and raw, are ed by ligno-sulphonates nnin. Other methods rial	Either manually or by special fittings into the tender water	Ligno-sulphonates tannin materials	Except with the « TIA » system, which is on trial, partial blow down is done on ashpits. Extraction rate 5 %
nical treatment	Except in some plants where there is automatic introduction by ejector or saturator, it is normally manual	Nalco or DisKro	Generally, by manually-operated continuous blow-down; some locomotives are fitted with continuous blow-down devices operated by steam. Hand type is preferred. Extraction rate about 6 %
ral internal treatment A »	Dosing done automatically, in tender water; this method is considered most convenient	Complex	Steam-operated valve. Extraction rate varies between 2 and 5 %
ral internal treatment A »	Generally by a special fitting on the tender	Complex	Double clack, steam operated
A » treatment o treatment	In the tender by automatic devices In the tender by hand	« TIA » complex Nalco	By means of a hand operated valve, with a recorder. Continuous blow-down at open regulator

The *F.S.* state that in applying the Franco-Crosti system, care must be taken to avoid excessive counter-pressure in the exhaust; on the locomotives mentioned above, counter-pressure has been reduced to the values which were obtained at the same powers in a normal locomotive, i.e. before conversion.

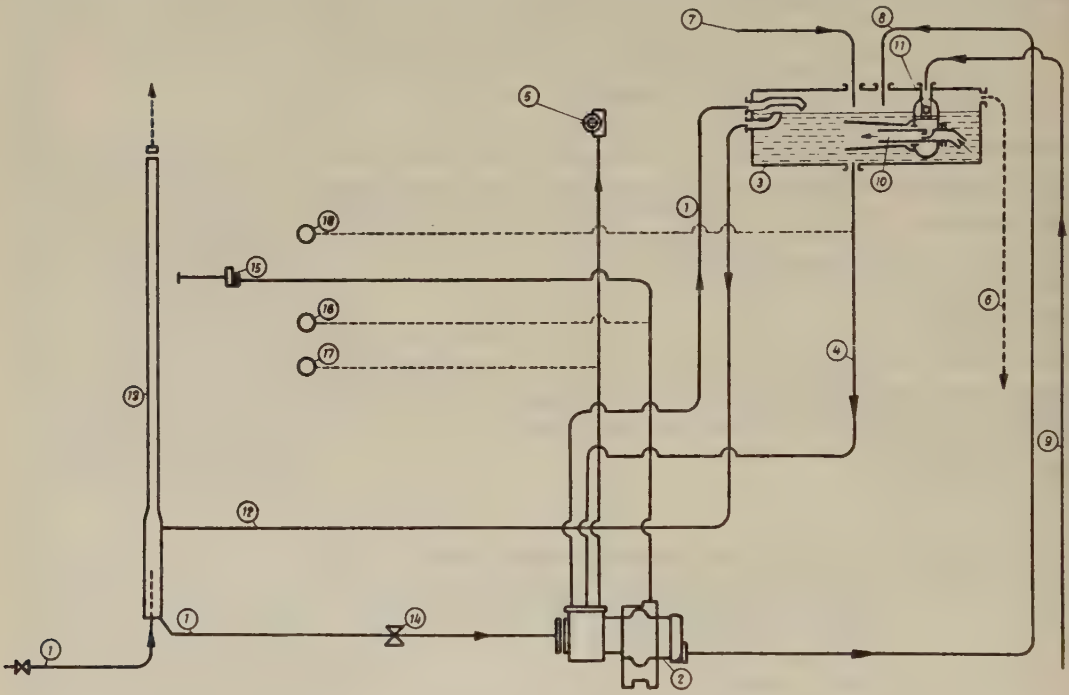

Fig. 11. — *D.B.* Diagram of Henschel preheater.

1) Water from tender.
2) Preheater turbo-pump.
3) Mixing chamber.
4) Hot water.
5) Boiler feed cock.
6) Air outlet.
7) Exhaust steam for air pump.
8) Exhaust steam from pump.
9) Exhaust steam from cylinders.
10) Mixing pipe.
11) Ball valve.
12) Overflow.
13) Air outlet.
14) Non-return valve.
15) Live steam control valve.
16) Steam pressure gauge.
17) Water gauge.

The Franco-Crosti boiler may also allow the use of an exhaust steam injector with a certain resultant advantage in efficiency (rather less use of gases [25 ± 30° C] but using the exhaust steam calories and economising in the consumption of live steam for the pump) by restricting the use of the pump to the periods when the regulator is closed and for any special requirements.

The general opinion is that in the case of new locomotives preheaters should be fitted; with existing locomotives which are not fitted with them, there is a tendency to provide them, especially on fairly recent types used for heavy services with few stops.

The *D.B.* which has more than 9 000 surface preheaters, intends to keep them in service for the present and to undertake a certain amount of replacement according to the means available; on locomotives of recent construction, they have fitted the Henschel mixer type (fig. 11) with turbo-pump, but the type at present preferred by the *D.B.* and by the *Ö.B.B.* is the Heinl type, because of the two stage preheating and the piston feed pump.

In fact, the Heinl type at the second stage heats the water to a temperature appreciably above 100° C which increases efficiency and may also allow an increase in the evaporative capacity of the boiler, even if this has already been calculated for feed water of 90 to 95° C. A similar characteristic but to a more pronounced degree is offered by the Franco-Crosti system, which can heat the water up to 140° C and even higher, according to the rate of combustion. This combustion gas preheater gives a greater fuel economy than any of the others; it involves however high installation costs and from this point of view its application may be more suitable for new locomotives or new boilers, for which it might be possible to have smaller dimensions, or where it is desired to obtain a big increase in evaporative capacity.

Summaries.

— All modern locomotives are fitted with feed water preheaters.

— Mixer type preheaters are preferred to surface type and exhaust steam injectors.

— The use of combustion gas economisers in the smokebox has not been extended.

— The combustion gas preheater is capable of giving beneficial results in suitable conditions.

— The importance of preheaters is generally emphasised when locomotives are heavily worked or when the boiler dimensions are relatively small compared with the engine requirements.

E. Treatment of feed water.

Physical lineside water treatment has been abandoned, except on the *R.E.N.F.E.*; trials in this connection by the *F.S.* and by the *Ö.B.B.* using electronic, magnetic field, ultrasonic, etc., devices have not given satisfactory results.

Although fixed installations for bulk treatment are still widely used, chemical water treatment directly on the locomotive is increasing. It is still experimental on several railways but is generally adopted on others (*S.N.C.F., F.S., S.N.C.Lux.*, etc.). Table L summarises the details relative to water treatment, supplied by the various Administrations.

Reagents are introduced into the tender whenever water is taken, proportional to the amount of water, either by an automatic device or by hand.

Several Administrations prefer the first method, which gives a more exact dosage. The *F.S.* started with this method, but changed over to the second, which is more economical and allowed treatment to be effected rapidly on all locomotives.

Control of the treatment on the basis of analysis, is designed to maintain hardness, alkalinity and salinity of boiler water below certain limits (generally 0° hardness).

Administratively, there is a central organisation which investigates the subject generally and a local organisation at Depots, which is directly responsible for treatment; on the *S.N.C.F.* and the *S.N.C.B.* the organisation is in three stages, Central, Regional and Local.

The treatment causes scale-forming salts to be precipitated in the form of sludge; it is however necessary to effect systematic clearance of the boiler by blow-down to reduce the amount of salts in solution (mainly sodium chloride and sulphate) and sludge in suspension.

Instead of continuous automatic blow-down preference is generally given to intermittent blow-down operated by the driver when running with the regulator open by means of a remotely controlled drain valve, operated either by steam (very widely used), by air or manually through mechanical transmission. (*F.S.*).

The extraction rate is not in direct proportion to the hardness of the water; it varies also according to the type of boiler, the service worked, the possible use of anti-

TABLE M. — ADVANTAGES OF INTERNAL WATER TREATMENT.

ADMINISTRATION	*Wash-out periods*		*Coal saving*	*Reduction in firebox work*		*Economies achieved*	*Remarks*
	before treatment	*after treatment*		*Maintenance and intermed. repairs*	*Major repairs*		
S.N.C.F. . . .	2 500 km	12 000 km sometimes up to 20 000 km	5 %	80 to 90 %	The periods between general repair are 600-650 000 km, instead of 320 000 km	30 fr/km for repairs; for benefits in use a further amount of twice this sum	
D.B.	15 days	30 days				2 480 D.M. loco/annum in respect of maintenance and intermediate repairs only	
Ö.B.B.		10-12 days (1) 90 days (2) 20-50 days (3) not yet settled (4)					(1) By the introduction of tri-sodic phosphate in the boiler at wash-out (2) « TIA » treatment (3) With « Aquasan » or « Tartrizite » (4) With Nalco
S.N.C.B. . . .		30 days					Internal treatments on trial, economy not yet assessed
F.S.	7 days	30 days, in some cases up to 100-180 days	5 to 6 %	45 to 50 %		13 lires/km	
R.E.N.F.E. . .	700 km 1 000 km 800 km	750 km 4 450 km 1 160 km	6.5 %	28.5 % labour 35 % material	24 %		
S.N.C. Lux. . .	10 days	60 days	3.4 %	91 %	80 %		
Portuguese Rys.	10 — 12 days	30 — 40 days					The two systems are in their initial phase : not possible to state a preference and establish economic results. It is admitted that by these treatments the life of the tubes is more than doubled.

primers. It is in general about 5 %; 2 to 5 % on the *R.E.N.F.E.*, 6 % on the *F.S.*

Table M summarises the main advantages which the various Administrations have obtained by water treatment.

The *S.N.C.F.* consider that economy in coal arises mainly from the great reduction in fire dropping and lighting.

With regard to the conservation of boilers, they state that :

— the results on locomotives treated from new are particularly good;

— water treatment has allowed the standardisation of steel fireboxes on the *S.N.C.F.* in spite of the quality of water used in France;

— water treatment permits more intensive working of locomotives, which all things being equal is equivalent to a reduction in total stock of about 30 %.

The *D.B.* has not so far been able to confirm any saving of coal; the *Ö.B.B.* considers that at present it may be that treatments which are subject to continuous blowdown do not effect any coal saving and in some cases even cause increased consumption. These two Administrations agree with the other advantages.

Foam conditions (overcarrying and priming) which tend to arise from water treatment, particularly when there is a high content of scale-forming salts, are efficiently overcome by the use of anti-priming reagents.

Stabilisers such as polyphosphates and tannin are widely used in the reagents to reduce considerably the incrustation of injectors, boiler feed pipes and scaling of smoke tubes where they meet the incoming water. With regard to the latter, water deflectors are used on a large scale and have been effective; the deposits formed on these are not hard and they can easily be cleaned off at wash-outs.

These problems must be dealt with individually and in every case it is possible to avoid any serious difficulty.

Some boiler fittings may be more or less subject to corrosion as a result of treatment :

— lead fusible plugs are certainly attacked; this is overcome by monthly renewal or by replacing them by Nathan type plugs. The *D.B.* no longer uses fusible plugs; the *F.S.* have on trial an anti-corrosive alloy (76 % lead, 14 % tin, 10 % antimony);

— with regard to bronze cocks, and lead cover packing, opinions are varied; in no case is there any very serious difficulty. The *F.S.* are experimenting with certain fittings of rustless steel and graphited asbestos joints;

— gauge glasses are generally attacked, particularly the tubular type; the *F.S.* have found it beneficial to use special Klinger glasses.

The types of corrosion mentioned above are the subject of investigation by several railways.

All Continental Administrations replying have shown a keen interest in locomotive feed water treatment; the same may be said of the *Cambodian Railways.*

The treatments generally preferred are those in which the reagents include emollients, stabilizers and anti-foams.

The economic results relative to either coal consumption or reduced labour and materials for maintenance and intermediate repairs, or to better service and more intensive user are considered very satisfactory by the Administrations which have used water treatment for a considerable time and as general practice; other Administrations which are at present in the experimental stage sometimes with differing procedures for comparison, have not yet been able to make a definite decision.

Summaries.

— Chemical treatment of water in locomotive boilers is of general interest.

— The reagents most generally preferred are those which have emollient, stabilising and anti-foam effects.

TABLE N. — LAGGING OF BOILERS.

ADMINISTRATION	*Materials used*	*Life*	*Coal saving obtained*	*Remarks*
S.N.C.F.	Aluminium coating, glass wool, magnesium blocks, magnesium plaster		Considered of little value	Thermal insulation is generally applied only to the firebox back plate for protection of personnel
D.B.	Glass wool	3-6 years	Theoretically about 4 tons of coal per annum for a series 38 locomotives	At present, insulation is limited to firebox back plate only. Extension to the whole boiler is being considered
Ö.B.B..	Waste fibre		1 to 2 %	Insulation for protection of personnel only
F.S.	Glass wool	3-6 years	Not determined in service, estimated at about 2 %	On some hundreds of engines only, insulation is extended to the whole of the boiler
R.E.N.F.E.	Mica, vitrofib, asbestos	Not determined	3 to 4.5 %	Firebox, barrel and sometimes steam cylinders are covered
Cambodian Rys.	Asbestos			Mattress between boiler and wrapper

— Treatment ensures considerable advantages as regards :

— the cost of boiler maintenance and periodical repair;

— the availability for use of locomotives and the resultant reduction in stock required, and capital charge necessary;

— coal consumption, in many cases at least;

— regularity of service.

F. Thermal insulation of the boiler.

Some Administrations effect insulation by a single wrapper plate; others restrict the insulation to the firebox to improve conditions for the engine crew; recently a tendency has been noticed to insulate the whole of the boiler. The materials used are shown in Table N.

In general, it has not been noticed that persistent steam or water escape has had such effect or duration as to affect the lagging.

The life of boiler lagging is considerable; from one general repair to another, and even longer, is reported by certain Administrations which use asbestos or wired glass wool mattresses.

Fuel saving in operation is assessed by several Administrations at about 3 to 4.5 %; the *Ö.B.B.* assesses it at 2 %.

Most Administrations incline towards greater boiler insulation; the *S.N.C.B.* however considers that the fitting of an insulating mattress causes difficulties which annul its advantages.

Summaries.

— Thermal insulation of boilers is being extended.

— The methods and materials used are still fairly widely different between Administrations.

— The saving of fuel is small but is achieved without any particular difficulty.

G. Exhaust.

Variable exhausts are no longer of interest.

The Kylchap and Kylälä types, which are well known, are fitted to a large number of modern locomotives by various Administrations (Table O) and at present seem to be preferred.

The *D.B.*, all of whose locomotives are fitted with ordinary blast pipes which have so far given every satisfaction, are at present considering undertaking tests with other types, including the Kylchap, to investigate the possibility of improvement.

The *Ö.B.B.* which has fitted most of its locomotives with « Filip » intermediate nozzle blast pipes, two years ago equipped three locomotives with « Giesl » blast pipes (fig. 12 includes the main dimensions) which has a special form of pipe, flat and elongated on the longitudinal axis with a chimney of corresponding shape. The lower part of the chimney is easily removed to give access to the smokebox; the spark arrestor is a simple inclined plate located behind the blast pipe.

The *Ö.B.B.* have in hand on the same series 113 locomotive, trials using alternately the ordinary blast pipe and the Giesl arrangement and have obtained with the latter, the smoke box vacuum being the same, a very large reduction in the steam back-pressure from the valves; in normal service there is a saving of about 5 % in coal consumption. In addition, the Giesl fitting has given no trouble in service; and the *Ö.B.B.* is consequently considering its wider application.

The locomotives with Franco-Crosti boilers also have chimneys (one or two according to the number of preheaters) with flattened section (fig. 13) to keep within the rolling stock gauge; this exhaust has multiple jets and orifices and is very efficient.

The diagrams in figure 14 show some blast pipe experiment results obtained by different Administrations; it may be noted that the function of the blast is to draw

TABLE O. — **BLAST PIPES.**

ADMINISTRATION	*Type of exhaust*	*Locomotives fitted*	*Max. rate of combustion*
S.N.C.F.	Kylchap	1 769	1 100 kg/m^2/h
D.B.	ordinary	all	750 kg/m^2/h
Ö.B.B.	Filip Kylälä Giesl	most loc. gr. 214 2 loc. gr. 113 + 1 gr. 729	600
S.N.C.B.	ordinary Kylchap Lemaître	loc. gr. 29 — gr. 10 loc. gr. 1 50 loc. gr. 7	
F.S.	ordinary Franco-Crosti	about all 135 loc.	500
R.E.N.F.E.	Kylälä Kylchap	most 107 loc.	450 to 500
Portuguese Rys.	multiple jets and orifices ordinary	58 loc. the majority	
S.N.C. Luxemburg	ordinary	all	
Madagascar Rys.	Kylchap	22	
Bas-Congo Ry.	Kylälä	all	
Cambodian Rys.	Kylchap	18	

through the boiler tubes the greater part of the combustion gases by means of the pressure drop in the smokebox; this pressure drop is, however, also dependent on the resistance to the passage of the gases, appropriate to the type of boiler and consequently any comparison of the ratios between smoke box vacuum and counter pressure in the tubes relative to different types of locomotive has no direct comparison.

The *F.S.* diagram, which refers to trials, with ordinary and Kylchap blast pipes, both on the same passenger locomotive, boiler pressure 16 kg/cm^2, grate area 3.50 m^2 (37.67 sq. ft.), simple expansion, shows results which do not vary very much in the two cases. The *F.S.* point out, however, that with the normal fitting, comprising a large diameter chimney, the height of the blast pipe was reduced to a minimum to increase

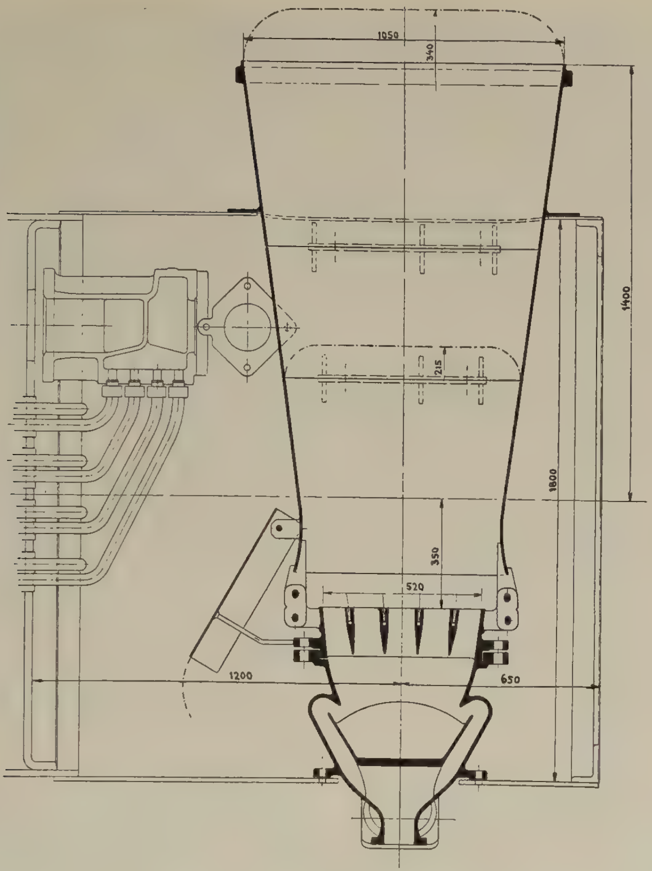

Fig. 12. — *Ö.B.B.* Giesl exhaust.

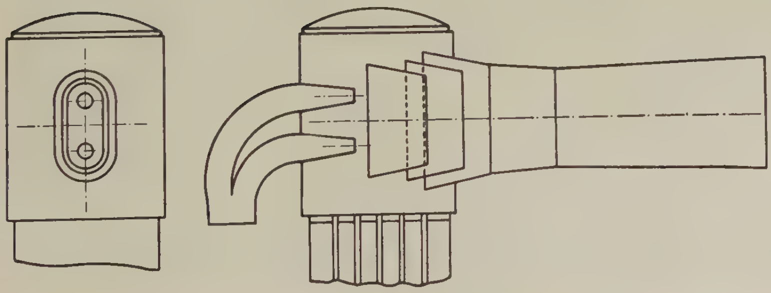

Fig. 13. — *F.S.* Chimney for Franco-Crosti boiler.

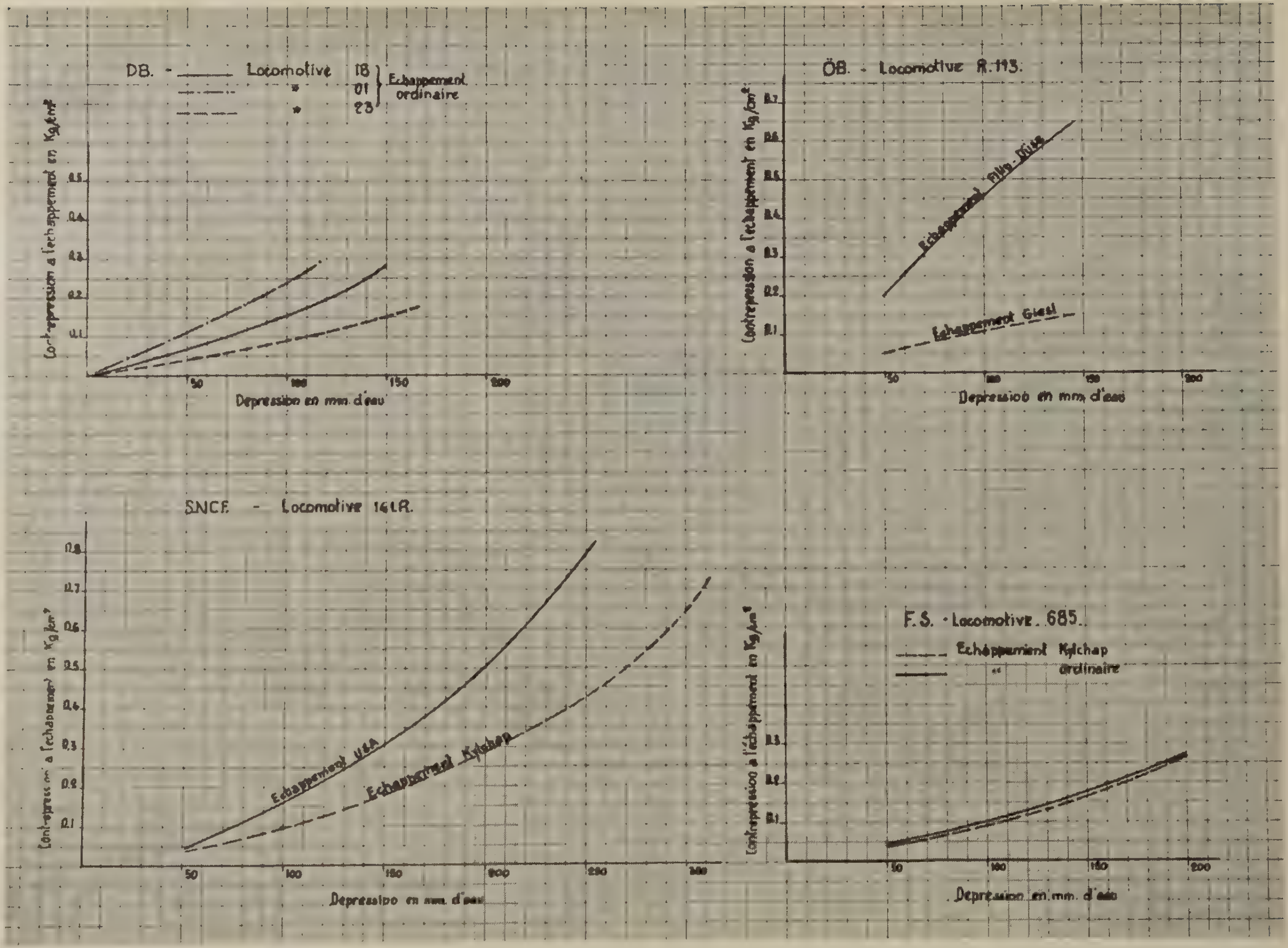

Fig. 14. — Exhaust diagrams.

Explanation of French terms:

D.B. Echappement ordinaire = D.B. Ordinary exhaust. — Contre-pression à l'échappement en kg/cm² = exhaust back pressure kg/cm². — Dépression en mm d'eau = vacuum in mm of water. — Ö.B.B. Echappement Filip Düse = Ö.B.B. Filip nozzle exhaust. — Echappement Giesl = Giesl exhaust. — F.S. Echappement Kylchap = F.S. Kylchap exhaust. — Ordinaire = ordinary.

Speed	*Cut off*	*141. R — 469 (American exhaust)*		*141. R — 874 (IK/IC exhaust)*	
km/h	*HP %*	*Power at rail HP*	*Coal consumption kg/HP-h*	*Power at rail HP*	*Coal consumption kg/HP-h*
40	40	1 432	1.160	1 739	1.132
40	60	2 197	1.442	2 269	1.418
60	35	1 995	1.144	1 980	1.112
60	55	2 600	1.534	2 736	1.467
60	60	—	—	2 844	1.583
80	35	2 223	1.262	2 200	1.150
80	45	2 633	1.558	2 655	1.334
80	55	—	—	2 928	1.956
100	35	2 291	1.412	2 307	1.238
100	45	—	—	2 700	1.633

the distance from the top of the chimney; it is only by this means that the results shown were obtained, but with such an arrangement which has subsequently been adopted for normal service, it is necessary to pay particular attention to the location of the blast pipe in relation to the centre line of the chimney whilst with the Kylchap exhaust the precision of centring has little importance and control of the fire is easier because distribution of draught over the grate is always regular.

In addition to the comparison of the diagrams of the Kylchap and U. S. A. exhausts on the series 141 R locomotive, the *S.N.C.F.* give corresponding details of consumption at different powers, reproduced in the table above, it can be seen that the locomotive fitted with the Kylchap exhaust consumed less coal per horse power hour at the drawbar whilst allowing a rise in the power factor.

Summaries.

— Despite the notable degree of efficiency achieved, the exhaust arrangement is still the object of investigations and trial, in view of its important effect on performance and the possibility of saving fuel.

— Variable exhausts have lost all interest and fixed exhausts of the standard type seem to be giving way more and more to newer designs.

H. Distribution.

In the construction of valves and pistons can be seen the tendency to achieve the lightest construction.

Whilst retaining the advantageous characteristics already obtained in steam distribution, efforts are made to modify port openings and to give a more progressive exhaust and so reduce the force of the beats which disturb the fire. Figure 15 shows a solution adopted by the *S.N.C.F.* for the H.P. and L.P. steam chests.

For valve gear, the *S.N.C.F.* in general prefer Walschaerts type, cylindrical piston valves with large area steam passages; but in the case of very high speeds, they state their liking for Walschaerts gear with oscillating cams and poppet valves which allow a considerable reduction of the effects of inertia and its bad influence on the behaviour of the mechanism. Valves controlled by rotary cams have not given such good results and they are not being retained by the *S.N.C.F.*

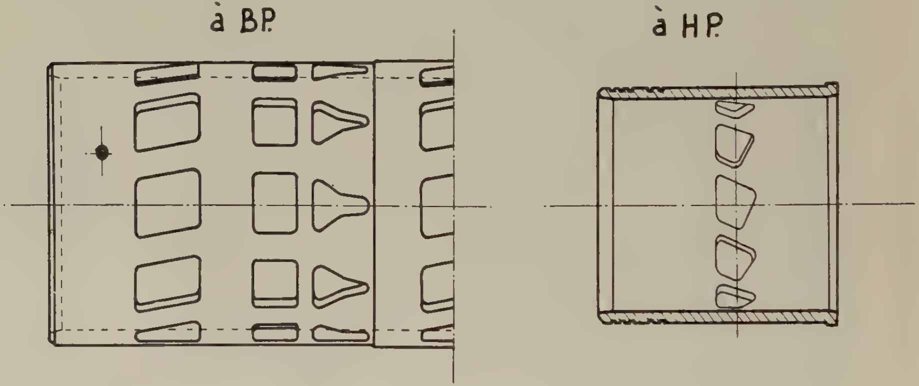

Fig. 15. — *S.N.C.F.* Valve liners.
à BP. = at LP.; à HP. = at HP.

Piston valves operated by rotary cams require excessive attention to the cam box because of the weight of the piston valves.

On the *S.N.C.F.*, the percentage of locomotives fitted with improved steam distribution (excluding shunting engines) is as follows :

Oscillating cam, poppet valves . . .	4.18 %
Rotary cam, poppet valves	0.11 %
Piston valves	0.91 %
Cylindrical, double orifice	7.53 %
Cylindrical with improved cylinder .	8.52 %

The *D.B.* generally use Walschaerts gear with cylindrical valves, which in the latest standard locomotives are of the Schulz or Müller types, both forming automatic by-pass. In the Schulz valve (fig. 16), which is very similar to the Nicolaï type, already reported to the 1937 Congress, each head is made up of two parts, the inner one being movable and held against the outer one by steam pressure; with a closed regulator, springs separate the two parts to give free passage between the two ends of the cylinder.

With the Müller valve (fig. 17), which has no spring, the two heads are always fixed but the inner includes a large slide valve with two concentric annular seats which by a small degree of slide open the by-pass when there is no steam.

The Müller type, the application of which is more recent than the other, has shown itself better in service from the maintenance point of view, but less efficient in compensation of pressure in the cylinder when running without steam (diagrams, fig. 18).

In trials at various times with poppet valves, the *D.B.* has obtained only negligible fuel saving; in actual service it has even been found that there was an increase. This is attributed to concentrated wear on the cams with a noticeable effect on the distribution and consumption of steam; this wear increases rapidly because of the considerable accelerations in force. The *D.B.* does not therefore intend to fit any further poppet valves.

The *Ö.B.B.* having in mind the characteristics of their lines, attach much importance to the conditions for running with closed regulator and are therefore inclined towards the use of poppet valve distribution which open when coasting, as fitted to their latest engines, or special by-pass types of cylindrical valves. Compared with cylindrical valves the *Ö.B.B.* estimate that there is a 3 % saving from the use of oscillating cams and that a higher saving can be obtained by rotary cams.

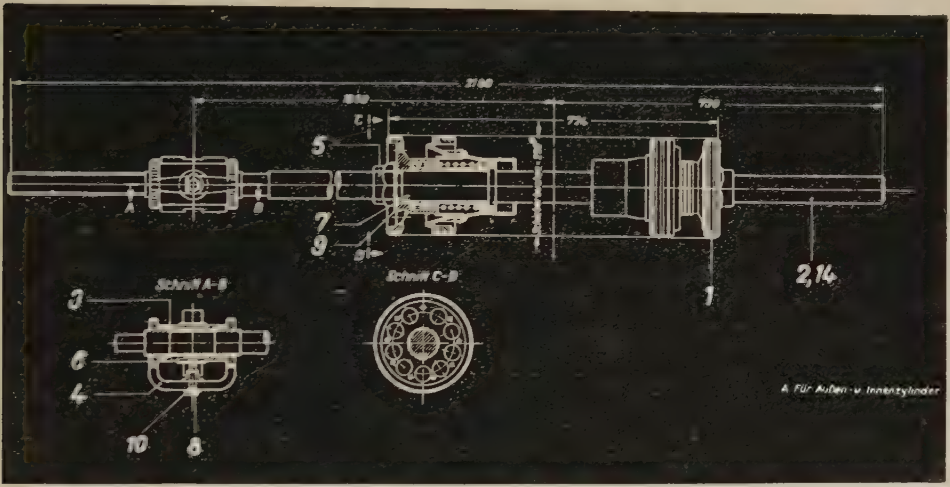

Fig. 16. — *D.B.* Schulz piston valve.

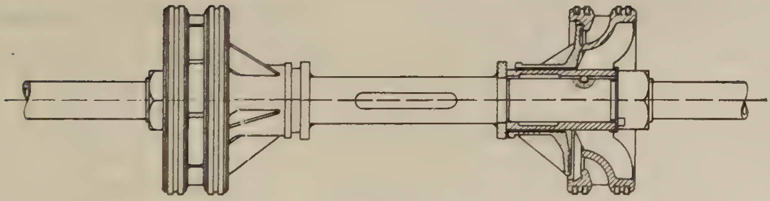

Fig. 17. — *D.B.* Müller piston valve.

The *F.S.*, which has for a number of years used the Caprotti rotary gear, report that compared with Walschaerts gear and cylindrical valves, there are moderate savings which vary according to the degree of wear on the cams and valves, greater smoothness of running at high speeds and with closed regulator and that maintenance is practically the same.

The *R.E.N.F.E.* uses with satisfaction on modern locomotives, the normal distribution with balanced piston valves or even, on most express locomotives with high superheat, oscillating cam gear of the Dabeg type and, more often, the Lenz type. The latter type is preferred and trials at present are in hand with this type and rotary cams.

Other Administrations use nothing but the normal Walschaerts gear and do not foresee any change; in particular the colonial railways do not favour poppet valves, because their operating conditions are not suitable for them, especially the need for more careful maintenance by specialised staff.

Coasting diagram, D.B. *locomotive series 50.*

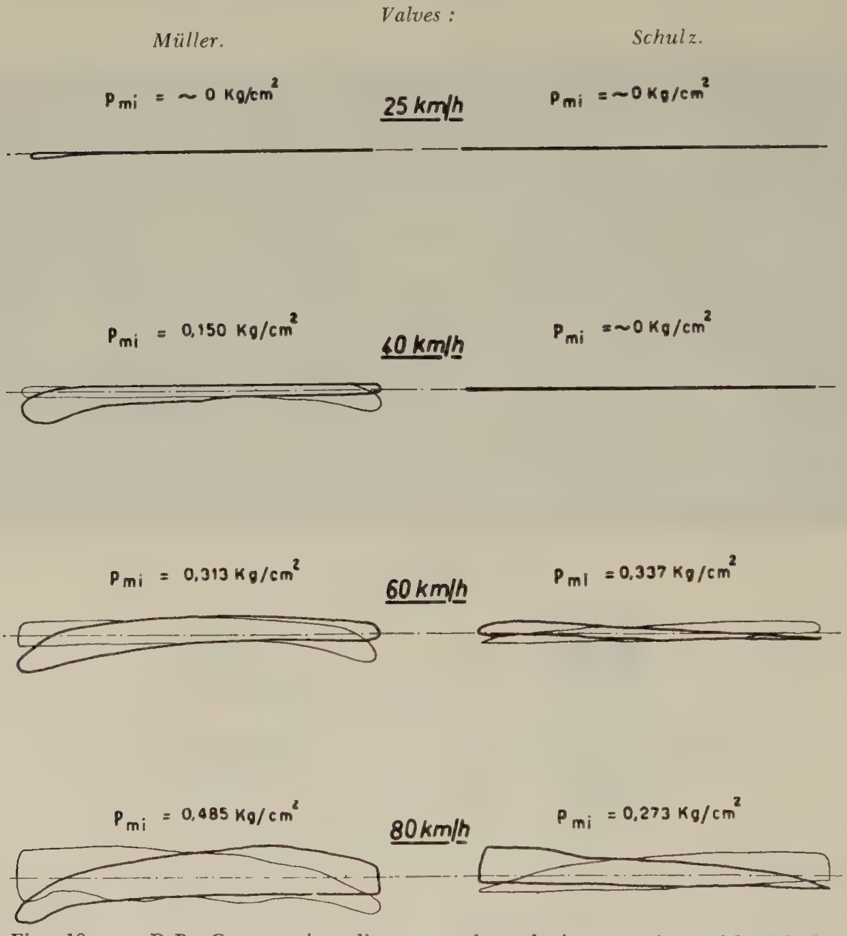

Fig. 18. — *D.B.* Comparative diagrams taken during coasting with Schulz and Müller piston valves.

Summaries.

— Preference for poppet valve gear as opposed to piston valves is not confirmed.

— The scope for application of poppet valves appears in all cases to be limited to express locomotives which are required to work a high percentage of their services with the regulator closed.

— The oscillating cam type is preferred to the rotary cam type because of its more stable operation and greater resistance to wear.

— Special valve gears including automatic by-pass for working with closed regulator seem to be having wider use by several Administrations.

I. Miscellaneous.

a) *Exhaust steam condensers (excluding mixer type preheaters).*

The use of condensers on piston locomotives has the special purpose of recovering water and any advantages affecting fuel consumption are only incidental. It must be recognised that the formation of sludge and scale in the boiler is reduced to a minimum but a condenser is costly, bulky, complicated and difficult to maintain, and its adoption can be justified only on particular railways where water supplies are widely separated.

The *D.B.* and the *S.N.C.F.* have over some time tested the Henschel type (*D.B.* series 52 loco.) but neither of these Administrations nor any other which has replied to the questionnaire are considering using in service the principle of almost complete recovery of water.

b) *Circulation of water in the boiler.*

On the *S.N.C.F.* most traffic locomotives built during the past 20 years have had Nicholson syphons and some have arch tubes; the *R.E.N.F.E.* has fitted 100 locomotives with Tobiac tubes and others with hydro-ejectors. Other Administrations do not at present show any interest in such fittings and the *D.B.* in particular considers that improved circulation of water in boilers with high pressure, temperature and specific evaporation should preferably be obtained by increasing the distance between the firebox sides and the cylindrical body of the outside shell boiler.

c) *Steam circuits.*

There is nothing new to report in this respect; it is confirmed that large steam passages are absolutely necessary to allow a fast locomotive to develop all the power of which it is capable.

d) *Air preheating.*

No Administration has adopted it or is considering trying it.

e) *Compounding of the drive.*

The various Administrations are divided in opinion as to whether compound locomotives need more maintenance than others, which in practice cancels the thermodynamic advantages; the *S.N.C.F.* however, shows in the Table below the possibility of achieving with the compound system very favourable consumption figures, particularly when approaching full use of the locomotive power. The comparison refers to counter-pressure locomotive trials with two modern *Pacific* engines having steam passages, high superheat, Kylchap double exhaust and ACFI feed water preheaters, one pressed at 20 hpz, 4.50 m^2 (48.43 sq. ft.) grate area and simple expansion 2 cylinders, the other pressed at 17 hpz, 4.33 m^2 (46.66 sq. ft.) grate area, 4-cylinder compound :

Power at drawbar HP	*Simple expansion locomotive*		*Compound locomotive*	
	Coal kg/HP-h	*Firing rate per m^2 grate area kg/h*	*Coal kg/HP-h*	*Firing rate per m^2 grate area kg/h*
1 630	1.05	380	0.95	360
2 405	1.32	705	1.02	570
2 625	1.55	905	1.15	700

The *F.S.* have carried out tests with the same type of passenger locomotive, 16 kg/cm² boiler pressure, 4.30 m² grate area, Walschaerts gear, in two versions, one 4-cylinder compound (four piston valves) conjugated gear, the other with four cylinders simple expansion (two piston valves) and find that with specially intensive working the compound type had a much lower coal consumption but in normal continuous service, the average amounts consumed by the two types were very much the same.

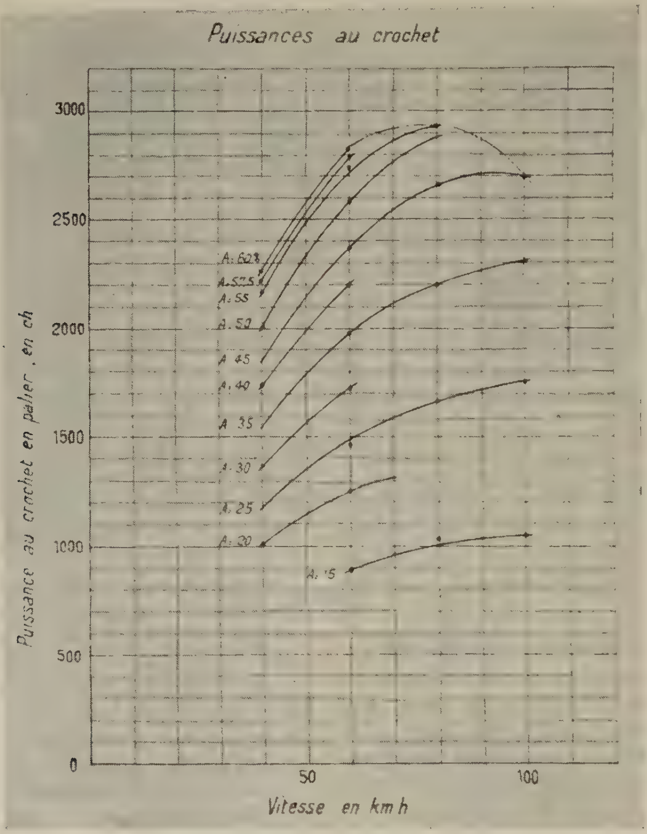

Fig. 19. — *S.N.C.F.* Power in relation to cut-off and speed. 141 R locomotive.

Explanation of French terms:

Puissance au crochet = power at drawbar. — Puissance au crochet en palier, en ch = power at drawbar on level track, HP. — Vitesse en km/h = speed in km/h.

f) *Streamlining of locomotives.*

Streamlining appears to be beneficial only for sustained speeds in excess of 120 km (75 miles)/h.

Streamlining, which first comprised a complete casing for the whole locomotive, has been modified by leaving the driving wheels clear to facilitate inspection and improve the flow of cooling air to the axleboxes and mechanical articulated joints.

The casings, which were largely developed before the war, have been dismantled and present practice is limited to the most obvious projections, particularly in the arrangement of pipework on the barrel or by a streamlined boiler casing.

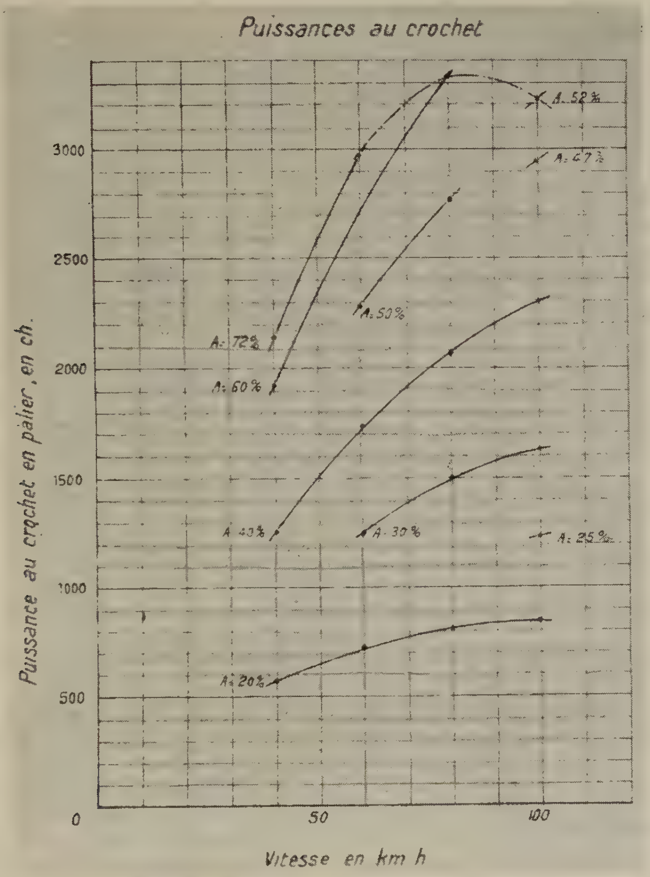

Fig. 20. — *S.N.C.F.* Power in relation to cut-off and speed. 141 P locomotive.

Explanation of French terms:

Puissance au crochet = power at drawbar. — Puissance au crochet en palier, en ch = power at drawbar on level track, HP. — Vitesse en km/h = speed in km/h.

Summaries.

a) Condensers for almost complete water recovery are at present of no interest for reciprocating engines; they relate solely to special cases.

b) Special devices for improving water circulation in the boiler are the subject of different opinions; it appears, however, that they are not being used on new locomotives.

TABLE P. — TEST RESULTS WITH D.B. LOCOMOTIVES 23 CLASS.

Results corresponding to full and 2/3 max. boiler evaporation. — D.B. series 23 locomotives. —	3/3	2/3
Total hourly evaporation per kg	10 900	7 340
Evaporation per m^2 total heating surface, kg . .	70	47
Combustion rate	530	280
Evaporation rate	6.6	8.4
Superheater temperature °C	405°	373°
Thermal efficiency of boiler	0.64	0.76
Maximum indicated HP	1785 (80÷110 km/h)	1 140 (75 km/h)
Effective power	1 485 (57 km/h)	925 (40 km/h)
Coal consumption at 60 km/h, kg per indicated HP/h	0.97	0.77
Coal consumption at 60 km/h, per effective HP/h kg	1.15	0.97
With normal coal of 7 600 cal/kg (low quality) reduced by calculation to 7 000 cal/kg		

c) It is still maintained that large steam passages are necessary for high speed locomotives.

d) Air preheating has been abandoned by all Administrations.

e) Between double and single expansion, preference inclines towards the latter which is less complicated and entails lower maintenance costs.

f) With regard to streamlining, the practice of overall casing has been abandoned and it is now limited to the more obvious projections; this is because of the fact that generally speaking very high speed trains are not now hauled by steam locomotives.

— Smokebox screens are used on a large scale.

L. Power and efficiency of modern locomotives.

Since 1937, several of the Administrations have built new locomotives or introduced major modifications to existing ones. The diagrams in figures 19 to 29 and Tables P and Q show the results obtained in trials with several of the new types, viz. the series 141 R (pressure 15.5 hpz) and 141 P (20 hpz) of the *S.N.C.F.*; S. 23 locomotives of the *D.B.* and S. 2400 and 4600 of the *R.E.N.F.E.*, the general characteristics of which are given in Table A.

On the locomotives in question :

— the evaporative capacity per m^2 of total heating surface reaches 70-75 kg/m^2/h with combustion rates of about 550

TABLE Q. — TOTAL EFFICIENCY AT DRAWBAR.

Speed km/h	40				60				80				100			
Series 141 P locomotive																
Cut-off	20	40	60	—	20	30	40	50	20	30	40	50	20	30	40	52
Efficiency %	8.06	8.74	8.33	—	7.82	8.83	9.06	8.51	7.03	8.43	8.4	8	6.72	7.74	8.09	5.46
Series 141 R locomotive																
Cut-off	20	30	40	50	20	30	40	50	25	35	45	55	15	25	35	45
Efficiency %	7.67	7.79	7.26	6.62	7.57	7.56	7.07	6.09	7.35	7.14	6.15	4.20	6.1	7	6.63	5.03

kg/m²/h and reaches 110 kg/m²/h at a rate of about 1 100 kg/m²/h (*S.N.C.F.*);

— the superheat temperatures in 141 P, 20 hpz *S.N.C.F.* locomotives reaches 370° and 385° C respectively for evaporations of 50 and 70 kg/m²/h (max. 418° C with 112 kg/m²/h) and in the S. 23 of the *D.B.* pressure 16 kg/cm², 375° C and 405° C correspondingly;

— the boiler efficiency, according to the types, is between 0.72 and 0.75 for a fuel consumption of about 300 kg/m²/h, it drops to 0.65-0.68 with a consumption of 500 kg/m²/h and to about 0.50 when the consumption is up to 1 000 kg/m².

These figures refer to the boiler alone; the efficiency of which appears to be little affected by the fitting of a preheater; if on the other hand, we consider the unit for the production of steam as a whole, including the preheater but excluding the steam used for oiler accessories, such as injector, etc., efficiency can reach remarkably high values as is shown for a variation in maximum value from 78 to 92 % by the diagram in figure 30 (¹) relative to *D.B.* series 42 locomotive fitted with Franco-Crosti preheater.

Power reaches 3 340 HP at the drawbar with a speed of 80-90 km (50-56 miles)/h for the 141 P locomotive of the *S.N.C.F.*; the *D.B.* reports 3 020 indicated HP for the series 45, freight locomotives which are the most powerful of the standard types.

— The indicated overall efficiency reaches a value of 0.118 and the effective efficiency 0.0949 on the *D.B.* series 23 with a rate of combustion of 270 kg/m²/h; on the *S.N.C.F.* these efficiencies are calculated at the drawbar and reach values of 0.0779 for the 141 R with a combustion rate of 280 kg/m²/h and 0.0906 for the 141 P with a rate of 360 kg/m²/h.

Summaries.

— The locomotives considered at the 1937 Congress and those built since do not

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(¹) Cf. *Eisenbahntechnische Rundschau*, No. 4, 1953 : Article by Dr.-Ing. Müller.

differ very much as regards power and efficiency.

— The effective overall efficiency of modern steam locomotives can reach under certain operating conditions a value of 9.5 %.

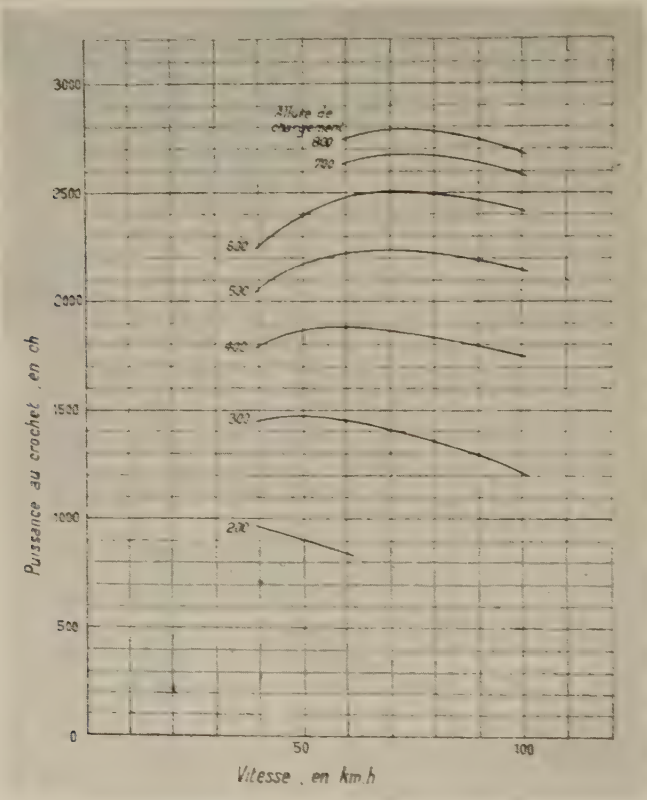

Fig. 21. — *S.N.C.F.* Power in relation to speed for a given hourly rate of firing. 141 R locomotive.

Explanation of French terms:

Allure de chargement = firing rate. — Puissance au crochet, en ch = power at drawbar, HP. — Vitesse en km h = speed in km h.

M. User and maintenance of modern locomotives.

Modern types in general form a considerable proportion of present day stocks of locomotives having regard to the fact that new constructions have been found necessary following the wartime losses.

Economic reasons call for an intensive user of locomotives and it is therefore found that there is a great increase in double and also triple turns even for passenger trains; this is particularly so on the *D.B.* which achieves a general average of 2.64 crews, and on the *S.N.C.B.*; it is interesting to find that there is complete interchange on the *S.N.C.F.* for passenger trains with the important 141 R series (1 323 locomotives).

The annual mileage is at present 80 000-90 000 km (50 000-56 000 miles) and on the *D.B.* approaches 145 000 km (90 100 miles) for certain types of passenger locomotives and nearly 90 000 km with some freight classes.

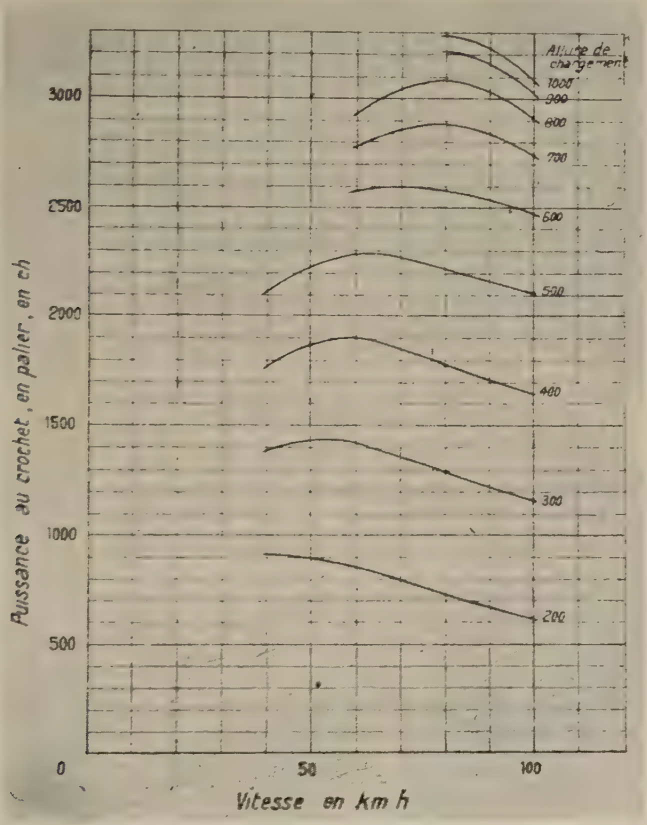

Fig. 22. — *S.N.C.F.* Power in relation to speed for a given hourly rate of firing. 141 P locomotive.

Explanation of French terms:

Allure de chargement = firing rate. — Puissance au crochet, en ch = power at drawbar, HP. — Vitesse en km/h = speed in km/h.

The longest journeys without engine changes (Table R) are at present undertaken in Germany with 525 km (Altona-Frankfurt a.M.) in passenger service and 440 km (Seelze-Mannheim) in freight service; the maximum non-stop distances are also on the *D.B.* with 277 km (Munich-Würzburg).

The tonnage of trains has generally increased; the *S.N.C.F.* reaches 800 tons with passenger trains at a commercial speed of 76.2 km (47 miles)/h on long runs (Le Mans-Brest), including gradients of 10 °/₀₀ and in other cases up to 850 tons (Le Mans-

TABLE R. — OPERATING CHARACTERISTICS OF SOME RECENT LOCOMOTIVES.

ADMINISTRATION AND CLASS OF LOCOMOTIVE	Maximum distance between engine changes		Maximum distance between stops	Types of train	Tonnage hauled	Maximum gradient	Maximum speed	Commercial speed	Commercial speed between two stops km/h
	Sections	km	km		t	mm/m	km/h	km/h	
D.B. :									
01	Aachen — Hamburg	522	—	Passenger	500	10	120	69	—
01^{10}	Altona — Frankfurt	525	—	»	500	12	120	68.2	—
01	München — Würzburg	—	277	»	300	—	120	—	79.1
01	München — Würzburg	—	277	»	200	—	120	—	86.9
44	Würzburg — Soest	384	—	Freight	600	12	65	50	—
44	Seelze — Mannheim	440	—	»	1 200	12	65	50	—
50	Emden — Rheine	—	143	»	1 500	—	65	41	—
S.N.C.F. :									
231. Gs/Est	Lyon — Marseille	351	125	Passenger	600	5	120	68.1	—
141. P	Le Mans — Brest	413	100	»	800	10	105	76.2	—
141. R	Le Mans — Nantes — Quimper	440	97	»	850	10	100	62.9	—
241. P	Lyon — Marseille	351	125	»	750	5	120	77.5	—
150. P	Lens — Le Bourget	225	98	Freight	1 700	8	105	34.8	—
R.E.N.F.E. :									
2 700	—	341	145	Passenger	400	18	100	57	—
5 000	—	122	60	Freight	—	16	49	—	—
S.N.C.B. :									
1	—	220	100	Passenger	600	16	120	80	—
7	—	200	60	»	500	13	110	70	—
10	—	220	100	»	600	16	120	75	—
29	—	165	60	Freight	1 720	16	96	40	—
26	—	167	60	»	1 750	16	80	40	—
Ö.B.B. :									
214	Wien — Villach	372	—		500	5		46	—
Cambodian Rys.									
231-500	—	273	28	Simple	550	—	45	—	—

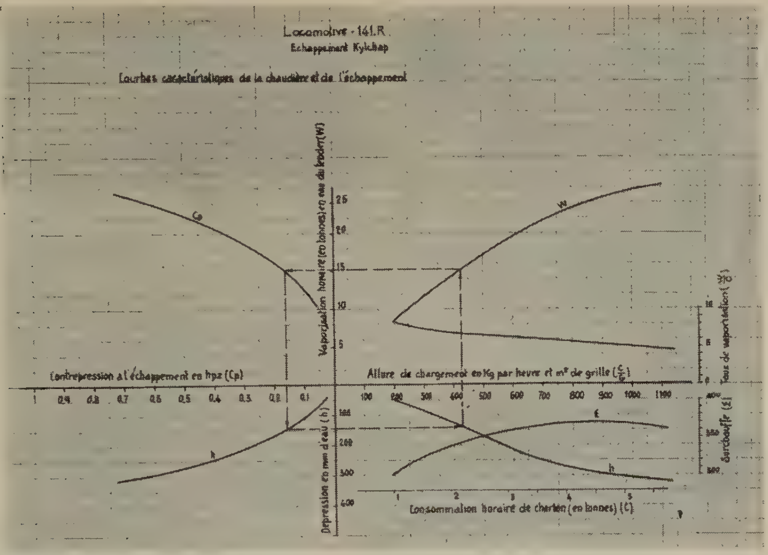

Fig. 23. — *S.N.C.F.* Characteristic curves of boiler and exhaust. 141 R locomotive.

Explanation of French terms:

Echappement Kylchap = Kylchap exhaust. — Vaporisation horaire en eau = hourly evaporation (tons) of water (W). — Contrepression à l'échappement = exhaust counterpressure (Hpz) (Cp). — Allure de chargement par heure et m² de grille = firing rate kg/h/m² grate area (C/g). — Dépression en mm d'eau = vacuum in mm of water. — Consommation horaire de charbon = hourly coal consumption (in tons). — Surchauffe : taux d'évaporation = superheat : rate of evaporation (W/C).

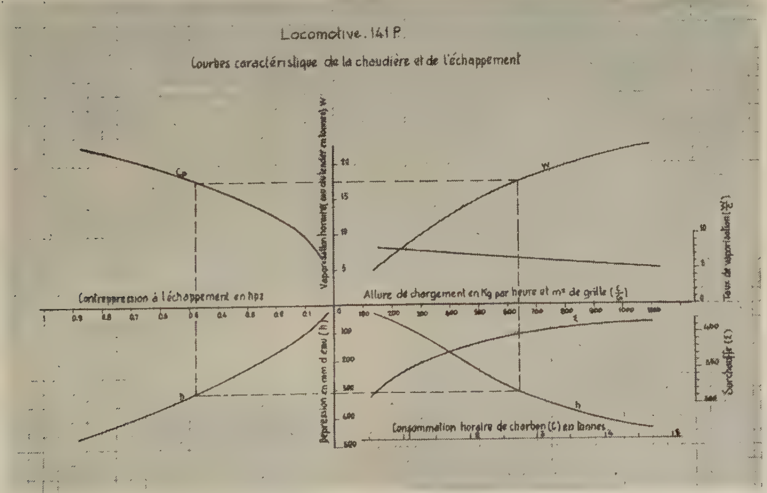

Fig. 24. — *S.N.C.F.* Characteristic curves of boiler and exhaust. 141 P locomotive.

(See fig. 23 for the explanation of the French terms.)

Nantes-Quimper). Freight trains frequently exceed 1 000 tons, even on difficult lines and reach even higher tonnages at considerable speeds : 1 500 tons on the *D.B.* at 41 km (25 miles)/h, 1 700 tons at 34.8 km (21 miles)/h on the *S.N.C.F.* and 1 750 tons at 40 km (25 miles)/h on the *S.N.C.B.*

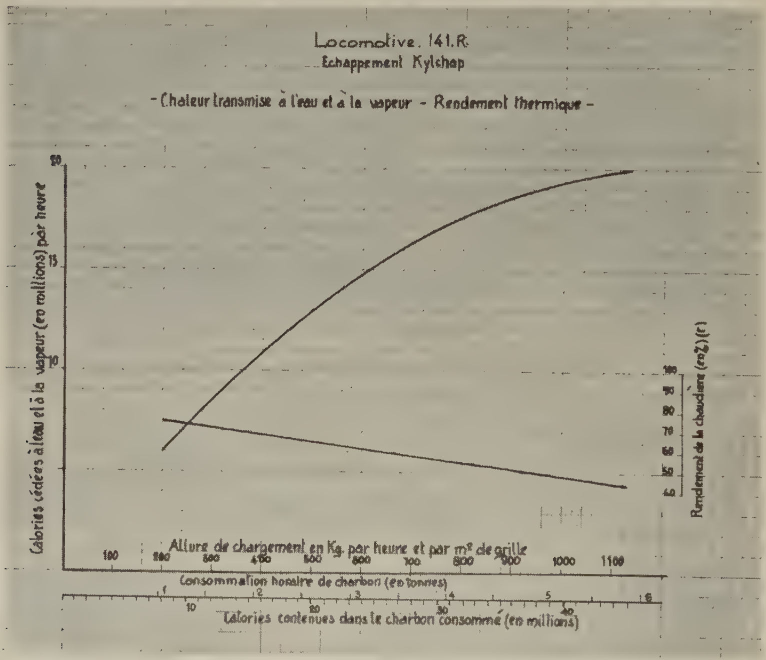

Fig. 25. — Heat transferred to water and steam. Thermal efficiency. 141 R locomotive.

Explanation of French terms:

Echappement Kylchap = Kylchap exhaust. — Calories cédées à l'eau et à la vapeur (en millions) par heure = calories transferred to water and steam (million/h). — Rendement de la chaudière = boiler efficiency (%) (r). — Allure de chargement par heure et m² de grille = firing rate kg/h/m² grate area. — Calories contenues dans le charbon consommé (en millions) = calories in coal consumed (millions). — Consommation horaire de charbon en tonnes = hourly coal consumption (tons).

It may be noted that whilst the commercial speed of freight trains tends to increase, with passenger trains hauled by steam locomotives it does not in general approach the high speeds of 100 km (62 miles)/h and above reached in special cases before the war. This is a result either of the after-effects of the war itself, or of the extension of electrification (on important lines), or because of the wide use for high speed trains of motor coach sets.

— The maintenance costs per km for modern steam locomotives are set out for certain railways in Table S.

Summaries.

— Journeys without engine change reach 525 km (326 miles) with passenger trains and 440 km (273 miles) with freight trains. Maximum distances between stops are at present 277 km (172 miles). Maximum commercial speeds for steam hauled passenger services are generally lower than pre-war.

— Modern locomotives are intensively used and achieve annual mileages at the present time of 80-90 000 km (50 000-56 000 miles) and even 145 000 km (90 100 miles) (*D.B.*); working with two or even three crews has been considerably extended and common usage of locomotives is also practised on a wide scale (*S.N.C.F.*).

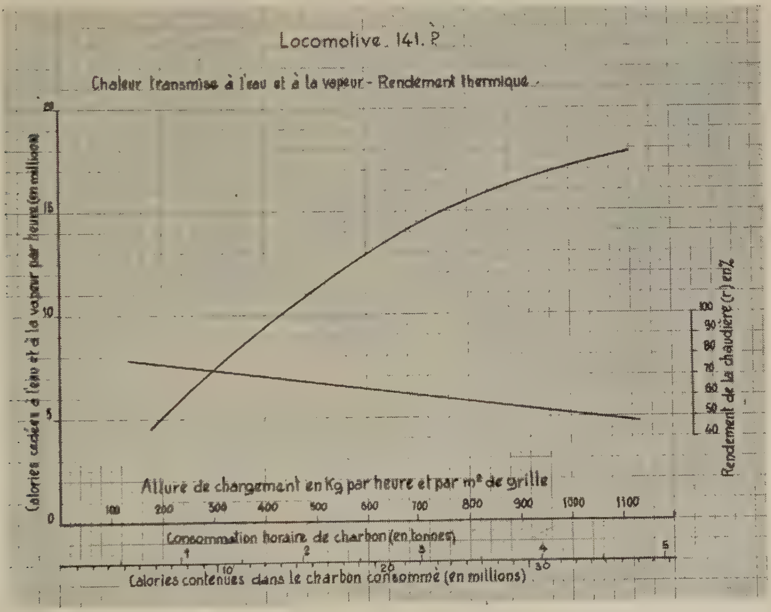

Fig. 26. — Heat transferred to water and steam. Thermal efficiency. 141 P locomotive.

(See fig. 25 for the explanation of French terms.)

N. Present position of the steam locomotive and future prospects.

Having regard to the importance of the question, it seems advisable to consider the replies from the various Administrations separately.

On the *D.B.*, steam locomotives represent 94.7 % of the stock; electric locomotives 4 % and diesel 1.3 %, but the steam traction undertakes only 85.6 % of the locomotive mileage and 89.6 % of the gross ton/km.

The programme of rationalisation and technical modernisation on the *D.B.* includes a scheme for the electrification of about 4 600 km (2 858 miles) of main lines and the gradual extension of diesel traction for shunting, for secondary lines with fairly light traffic and for light trains for high speed, long distance services (motor coach sets or light trains hauled by a diesel locomotive). This programme will be developed in line with the comparative prices of coal and heavy oil.

Within the framework of the programme for the construction of new locomotives drawn up by the *D.B.* in 1949, series 23 for stopping trains have already been put into service, representing the most recent locomotive building by the *D.B.*, also two

TABLE S. — MAINTENANCE C

ADMINISTRATION	*Class of locomotive*	*Boiler pressure*	*Simple expansion or compound*	*Date built*	*Number of locomotives*	*Service*	*Worki of crew*
S.N.C.F. . . .	231. GS/Est	16 hpz	compound	1932	211	passenger	single
	141. P	20 hpz	compound	1942/52	316	»	single and dou
	141. R	15.5 hpz	simple expansion	—	1 323	»	common
	241. P	20 hpz	compound	1948/52	35	»	single
	150. P	18 hpz	compound	1939/51	113	freight	single
D.B.	01	16 kg/cm²	simple	1925	219	passenger	double and trip
	01^{10}	16 »	simple	1937			
	03	16 »	simple	1930	171	»	»
	03^{10}	16 »	»	1937			
	41	16 »	»	1934	216	freight	»
	44	16 »	simple or compound	1925	603	»	»
	50	16 »	»	1939	2 075	»	»
S.N.C.B. . . .	1	18 »	simple expansion	1934	34	passenger	double
	7	16 »	compound	1935	73	»	double and trip
	10	14 »	simple	1909	49	»	»
	29	15.75 »	»	1945	300	freight	»
	26	16 »	»	1945	90	»	»
Ö.B.B.	214	15 »	simple	1931	4	passenger	double
	113	15 »	»	—	33	»	single
	729	13 »	»	1931	26	»	»
	52	16 »	»	—	218	freight	multip
R.E.N.F.E. . .	2 700	16 »	»	1951	57	passenger	single
	5 000	—	»	—	22	freight	single and dou
S.N.C. Luxemburg	47	16 »	»	1946	10	mixed	multip
	55	16 »	»	1947/48	10	»	»
	56	16 »	»	1946/47	20	freight	»

RIOUS KINDS OF LOCOMOTIVES.

erage nual leage km	*Maintenance cost per km (1952)*							
	expressed in	*Works general repair*	*Depot repair*	*Depot inter-mediate repair*	*Depot current main-tenance*	*Shed attention (washout)*	*Total*	
050 000	French francs	24.9	38.3	6.5	36.4	3.5	109.6	
264 000	»	40.4	39.3	6.1	30.3	2.3	118.6	
938 000	»	17.5	15.1	2.3	19.7	2.3	56.9	(1) Mileages per series of locomotives
758 000	»	22.1	21.3	4.8	27	1.9	77.1	
350 000	»	37.6	46.5	9	32.7	3.3	129.1	
		in repair shops			at depot			
125 160	marks	0.322			0.148		0.470	
144 190	»							
111 340	»	0.265			0.157		0.422	
118 960	»							
87 540	»	0.343			0.152		0.495	
61 880	»	0.428			0.238		0.666	
53 260	»	0.367			0.194		0.561	
90 000	Belgian francs	5.19			5.17		10.36	
72 000	»	3.46			3.15		6.61	
90 000	»	4.43			3.96		8.39	
60 000	»	3.07			1.92		4.99	
60 000	»	3.29			3.50		6.79	(2) Mileages per locomotive
88 000	schillings	2.10			1.23		3.33	
75 000	»	1.94			0.68		2.62	
50 000	»	1.86			0.74		2.60	
37 000	»	2.68			1.14		3.82	
65 000								
40 000								
44 000								
40 000								
53 000								

classes of tank locomotives, whilst the series 10 for fast trains and another type of tank locomotive are in the design stage. These five classes, which it is expected will total 115 locomotives, comprise the whole of the present new building programme of the *D.B.* in this direction.

The *D.B.* thus anticipates a reduction in the overall use of steam locomotives, which will however during the next ten years keep a predominant position because the capital needed for electrification can only be gradually acquired; it is considered that, in the not too distant future, the ratio of steam to electric locomotives will be 4 700 to 2 200.

The *S.N.C.F.* (steam locomotives more than 10 000, electric 996, diesel 158) fol-

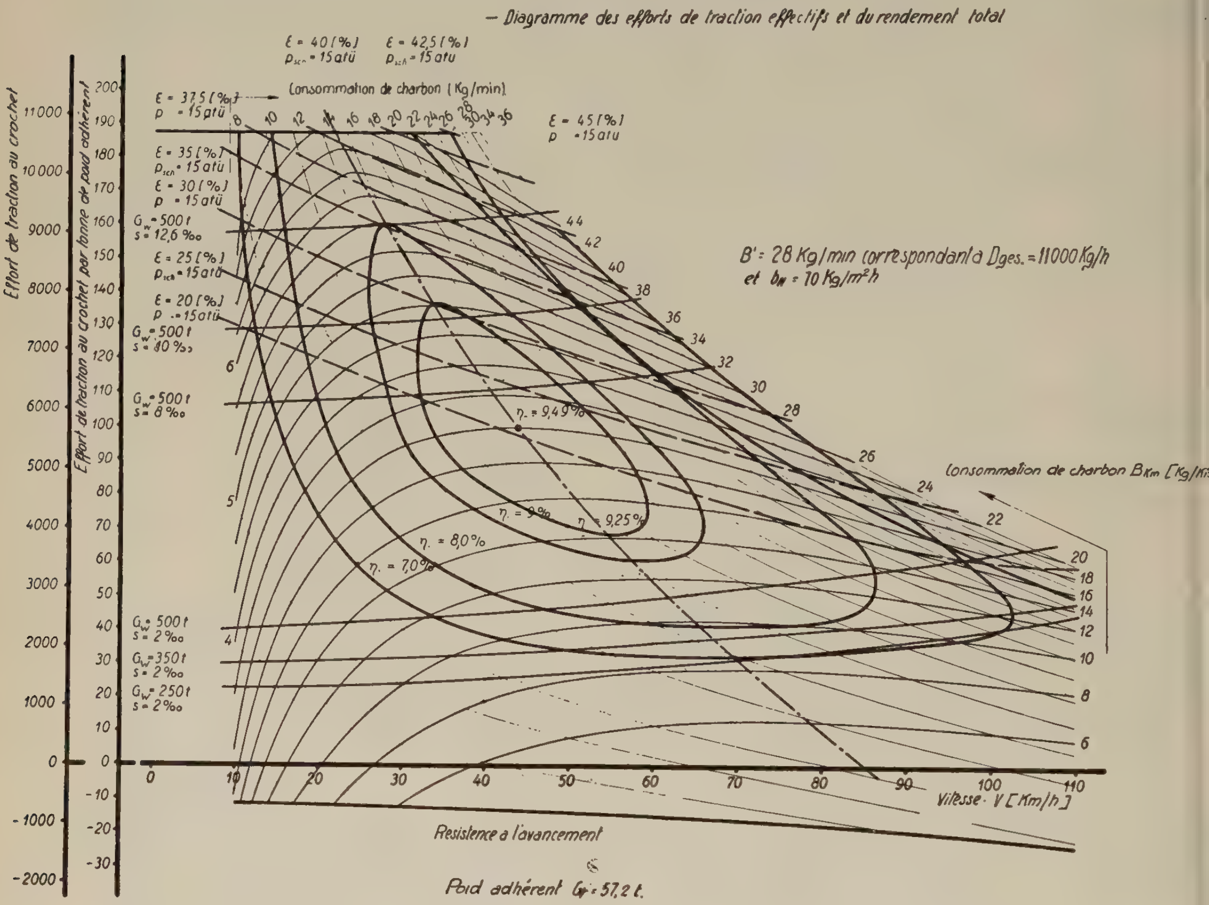

Fig. 27. — *D.B.* Diagram of tractive efforts and total efficiency. Series 23 locomotive.

Explanation of French terms:

Effort de traction au crochet = tractive effort at drawbar. — Effort de traction au crochet par tonne de poids adhérent = tractive effort at drawbar per ton of adhesive weight. — Consommation de charbon = coal consumption. — Résistance à l'avancement = resistance to movement. — Poids adhérent = adhesive weight, 57.2 tons.

lowing the extension of electrification, the use of Diesel locomotives for shunting and railcars for secondary feeder services, does not intend to build any steam locomotives.

The *F.S.* (steam locomotives 3 200, electric 1 500, diesel 60) having 5 790 km of lines of which 3 039 km are double track, already electrified out of a total of 15 871 km (4 224 km double track) are gradually extending electrification to other important lines, replacing steam locomotives for shunting, extending railcar services and are considering the use of Diesel locomotives for certain secondary lines. The construction of steam locomotives ceased more than 25 years ago.

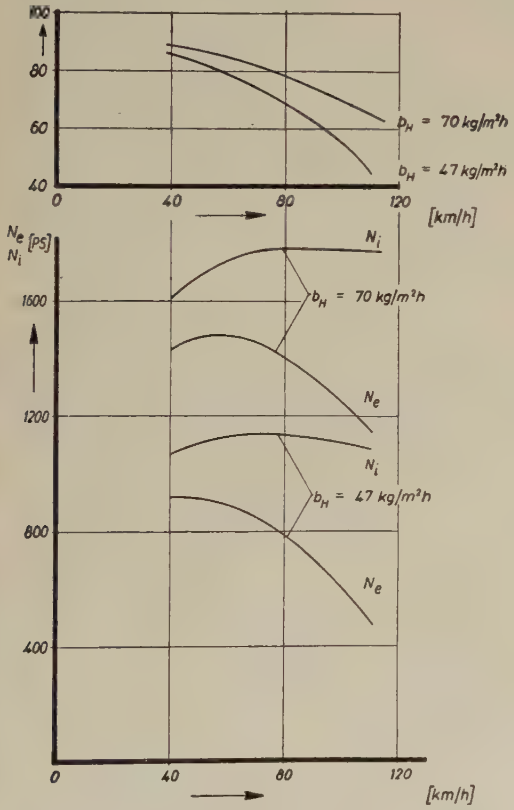

Fig. 28. — *D.B.* Mechanical efficiency; effective and indicated HP at maximum and two-thirds positions. Locomotive series 23.

The *R.E.N.F.E.* which has 3 375 steam locomotives, has under construction 137 of three different types burning fuel oil.

The *S.N.C.B.* (steam locomotives 2 269, electric 29) intends to electrify certain lines, to put into service Diesel locomotives and to reduce the number of steam locomotives.

On the *Ö.B.B.* (steam locomotives 1 223, electric locomotives and motor coaches 307, Diesel a few tens), steam locomotives still represent 75 % of the stock, but they undertake only 60 % of the total mileage run and 55 % of the total tonnage hauled. In 10 years, 80 % of the total tonnage will be hauled by electric and Diesel locomotives.

The *Portuguese Railways,* who have 398 steam locomotives and 29 Diesel locomotives, operate with the latter the most important services; they foresee a strongly marked reduction in steam traction and consider the electrification in the near future of a somewhat important part of their system.

The *Swiss Federal Railways* have since 1918 systematically electrified their system and at present only 110 km (68 miles) of line and some yard shunting is still undertaken by steam locomotives which, it is intended, should be gradually displaced.

The *S.N.C.Lux.* has 131 steam locomotives in service and some Diesel shunters under construction.

The *Bas-Congo Railway* has 157 steam locomotives, 12 electric and 2 Diesel; there are 12 Garratt steam locomotives on order.

The *Madagascar Railways* (60 steam and 10 Diesel locomotives) anticipate building 20 Diesel locomotives.

Many of the Administrations amongst those mentioned above thus show a more or less marked tendency towards a progressive extension of traction other than steam. This tendency, even if it is not always crystallized by notable practical effects, is nevertheless of such a kind as to impede the development of steam traction which will naturally continue to be used in certain cases perhaps for ten or more years to come, but with a progressive reduction in the number of units and with in general no new building.

The following Table (¹) shows the percentages for several railways of km/motive unit for various types of power and is very significant; it refers to the position in 1950 :

Types of traction :		*Germany*	*Austria*	*Denmark*	*France*	*Italy*	*Holland*	*Switzer-land*
steam	%	88.1	71.7	56.3	64.8	33.2	55.5	7
electric	%	8.1	25	13	19.8	45.7	35.4	92.2
diesel	%	3.8	3.3	30.7	15.4	21.1	9.1	0.8

It may be worth considering that an electric locomotive replaces 1.6 or 2 steam locomotives and that the lines electrified are essentially, as a general rule, those with heavy and dense traffic.

Moreover, many passenger trains on main lines, secondary lines, or light trains on main lines, or even long distances light express trains can be worked by railcar sets which, because of more frequent and faster connections, are better able to meet road competition. The *S.N.C.F.* and *F.S.* for example already have a stock of about 800 railcars.

With regard to African and Colonial Railways, certain of them on which steam traction is already handicapped by water shortage, the high price of coal delivered to the consuming point, and by other drawbacks connected with the special features of their services, can show a real case for replacing steam by Diesel power.

Summaries.

— Steam traction appears to have already reached its maximum state of development; most of the Administrations covered are not considering the construction of new steam locomotives.

— In future years it is possible to foresee, there will be in general a reduction in the number of steam locomotives in service and a gradual extension of other means of transport.

— The large scale replacement of steam traction will in any case require many years because of the necessary amount of capital outlay.

Résumé of the summaries.

A. — Increasing the boiler pressure is considered of value in improving efficiency and specific power of the locomotive, but beyond a certain limit it entails an increased cost of maintenance and even increased time out of traffic, which can seriously affect the financial benefit.

It is the general opinion that this limit is located between 16 and 18 kg/cm² (227 and 256 lbs per sq. inch); the *S.N.C.F.* alone considers that it would be beneficial, in newly-built powerful high speed locomotives to increase the pressure to 22 hpz. This seems to depend on the fact that this Administration has been able to resolve satisfactorily the problems of techniques connected with the use of special steels.

B. — Shaker grates are still widely used by railways burning coal with high clinker residue.

— The use of coal pushers has not been extended.

— Mechanical stoking has developed considerably but as it entails increased fuel

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(¹) Die Deutsche Bundesbahn und ihre Industrie. *Energiewirtschaft und Zugförderung :* Dipl. Ing. A. BRILL.

consumption its use should be restricted to locomotives with a grate area of at least 4.5 to 5 m² (48.43 to 53.82 sq. ft.) and high rates of combustion.

— The use of pulverised fuel has been discontinued.

— Oil-firing has reached a high standard and fairly wide use, which seems to continue; its economic advantage however varies in accordance with the relative prices of heavy oil and coal.

C. — Superheating of steam has not changed very much in recent years and a temperature limit of about 400° C for locomotives with a pressure of 16-18 kg/cm² (227-256 lbs per sq. inch) can be considered standard.

— With regard to the report to the Paris Congress of 1937, there is nothing to mention in this section on the introduction of new features; however, certain measures designed to improve the life of superheater elements and the steam-tightness and life of segmental piston rings are of particular interest.

D. — All modern locomotives are fitted with feedwater preheaters.

— Mixer type preheaters are moreover preferred to surface types and to exhaust steam injectors.

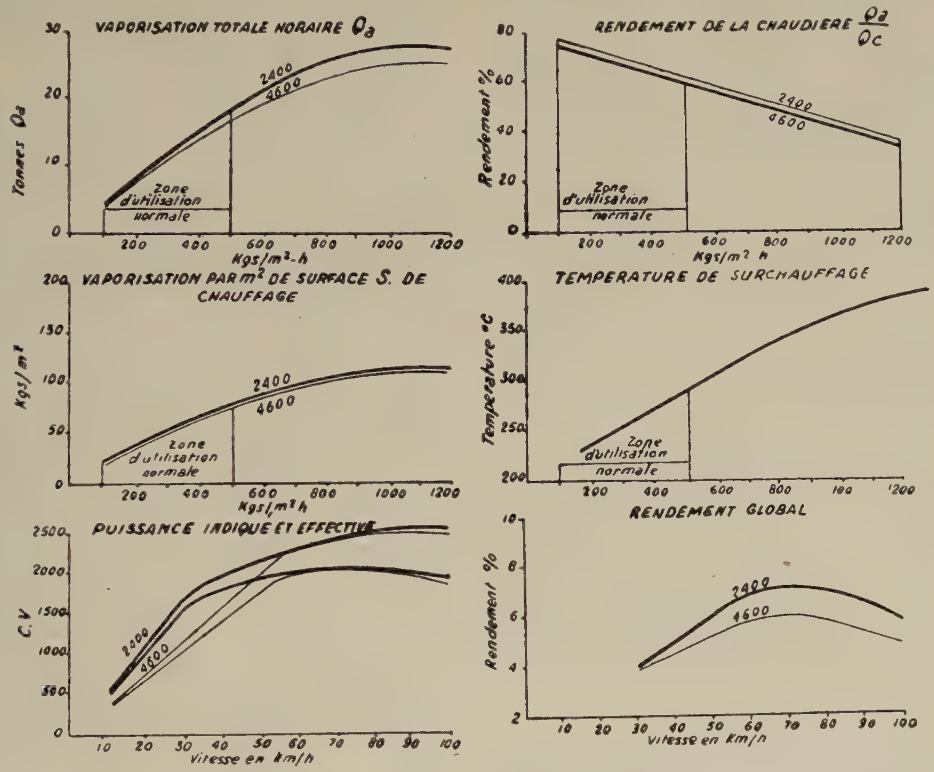

Fig. 29. — *R.E.N.F.E.* Graphs of tests with series 2400 and 4600 locomotives.

Explanation of French terms:

Vaporisation horaire totale = total hourly evaporation. — Rendement de la chaudière = boiler efficiency. — Vaporisation par m² de surface (S) de chauffage, zone d'utilisation normale = evaporation per m² of heating surface (S), normal zone of use. — Température de surchauffe = superheat temperature. — Puissance indiquée et effective = indicated and effective power. — Rendement global = total efficiency.

— The use of combustion gas economisers in the smoke box has not been extended.

— The combustion gas preheater may, in suitable conditions, give good results.

S 42 D.B. *locomotive with Franco-Crosti preheater.*

Efficiency $\left\{ \begin{array}{l} \eta = \textit{boiler alone;} \\ \eta' = \textit{boiler and preheater together.} \end{array} \right.$

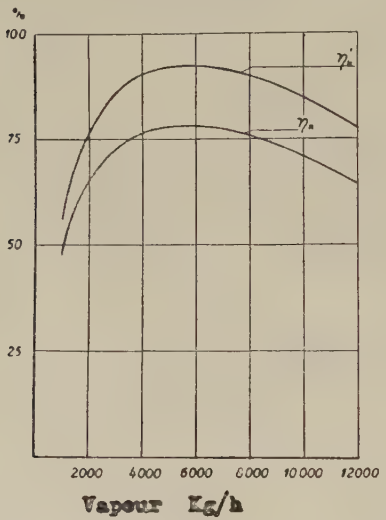

Fig. 30. — *D.B.* Efficiency of boiler and boiler-Franco-Crosti preheater group. S 42 locomotive.

— Preheaters show themselves in general important, particularly on locomotives which are heavily worked or are fitted with boilers relatively small compared with their tractive effort.

E. — Chemical water treatment in the boiler is of general interest.

— The reagents mostly preferred are those which by means of mineral or organic substances have a softening, stabilising and anti-priming effect.

— Treatment ensures considerable benefits in :

— cost of maintenance and periodical repairs to boilers;

— the availability of locomotives and reduction in stock and capital which results;

— coal consumption, at least in a number of cases;

— regularity of service.

F. — Lagging of boilers is being extended.

— Methods and materials used are still different between railways.

— The saving in coal is small but can be obtained without particular difficulty.

G. — Despite the high degree of efficiency achieved, the exhaust arrangement continues to be the subject of research and experiment because of its importance in performance and even in fuel consumption.

— Variable exhausts have lost all interest and fixed exhausts of the standard type seem to be giving way more and more to later designs.

H. — Preference for poppet valve gear over piston valves is not confirmed.

— The scope for fitting poppet valve gear seems in every case to be restricted to high speed locomotives and those which have a high proportion of running with the regulator closed.

— Oscillating cams are preferred to rotary cams because of their more stable operation and greater resistance to wear.

— Special valves with automatic by-pass for running with the regulator closed seem to be extending their application on several railways.

I. — Total recovery condensers have no general interest for reciprocating locomotives; they relate only to special cases.

— Special devices for improving circulation of water in the boiler are the subject of mixed opinions; it appears, however, that they are not being fitted in new locomotives.

— It is still considered that large steam passages are necessary in high speed locomotives.

— Air preheating has been abandoned by all Administrations.

— Between compound and simple expansion, favour inclines towards the latter, which is less complicated and involves lower maintenance charges.

— With regard to streamlining, the principle of complete casing has been abandoned and it is now limited to the more obvious projections; this is because, at present, high speed trains are not generally hauled by steam locomotives.

— Smokebox screens are used on a large scale.

L. — The locomotives considered at the 1937 Congress and those built since do not differ substantially in power and efficiency.

— The overall effective efficiency of modern steam locomotives, under certain operating conditions, attains a value of 9.5 %.

M. — Journeys without change of engine reach 525 km (326 miles) with passenger trains and 440 km (273 miles) with freight trains. Maximum non-stop distances are at present of 277 km (172 miles). Maximum commercial speeds of steam hauled passenger trains are generally lower than before the war.

— Modern locomotives are intensively used and achieve a current annual mileage of 80-90 000 km (50 000-56 000 miles) and even 145 000 km (90 100 miles) (*D.B.*). Multi-crew working (double and even triple turns) are widely used, and it is practised also to a large extent in the general user service (*S.N.C.F.*).

N. — Steam traction appears to have already reached its maximum stage of development; most of the Administrations covered do not intend to build any new steam locomotives.

— For future years, it is possible to forecast in general a reduction in the number of steam locomotives in service, and a certain gradual extension of other means of traction.

— The large scale replacement of steam traction will in every case require a number of years, because of the capital expenditure involved.

* * *

It may be considered permissible to add the following general comments.

At the Paris Congress in 1937, and at the Madrid Congress in 1930, the steam locomotive was the object of new ideas for its improvement from all points of view, going as far as proposals to abandon the standard designs in attempts to make definite advances in efficiency, power and speed.

Today, on the contrary, the steam locomotive is in a static condition of development; the more radical ideas have been abandoned, many others have shown that they have little contribution to make, and the standard design, fitted with the more rational of the suggested improvements, is still generally favoured, and has shown itself difficult to displace.

At the same time, it is the object of careful attention as regards the organisation of user and maintenance (to be noted the great importance of the chemical treatment of the water in the boilers) so to afford the best economic results from its operation.

At the present time, most of the Administrations with which we have been dealing, have no new steam locomotive building programme, but their stocks include many modern or fairly recent locomotives, such as those built since the war to make good wartime losses. Whilst Diesel shunters and railcars have obviously suitable fields of employment and electric traction is advantageous for certain lines with heavy traffic, the high proportion remaining, representing heavy freight and passenger trains, must be hauled either by modern steam locomotives or Diesel, not with regard to thermodynamic efficiency alone but the overall and true cost of operation seem to present some uncertainty and the choice appears still very susceptible to the comparative cost of coal and fuel oil as well as the depreciation rates of the Diesel locomotives to be built, the cost of which at present are excessively high.

In all cases, even for this last reason, the replacement on a large scale in a relatively short space of time of steam locomotives by Diesel or electric locomotives requires new capital investment of such importance that it would endanger the balance of capital structure and would moreover be difficult to find in view of the general financial crisis through which Railways are passing.

Whilst on several railways, steam traction has lost or is losing all interest, others, including the very large ones, will show for many years to come a majority of their rail-borne traffic hauled by steam locomotives which will be capable, without extensive new construction, of adopting technical improvements and other organisational measures which will be of considerable interest.

CORRIGENDUM

REPORT ON QUESTION 1 (LONDON CONGRESS, 1954), by C. FEYRABEND,

appearing in the *BULLETIN* for December 1953.

Page 1001/33 :

TABLE II. — Equipment of lines; column : « Sleepering (number of sleepers per kilometre) :

Swiss Federal Railways : Instead of 1556, it must be *1667.*

Page 1027/59 :

TABLE X. — Tools or machines used; column : « Type » :

SWITZERLAND. — C.F.F.: The mechanical tampers and screeners used on this system are exclusively of the « Scheuchzer » type.

APPENDIX III :

(Pages 1072/104 and 1073/105) :

Average annual maintenance costs converted into U.S.A. Dollars.

The figures relating to the *Netherlands Railways* (**Appendix III**) *(continued)*, **Part V.** — **Chapter A.** — § 4 (8th. column) must be modified as follows :

Daily output per km of track	*Netherlands Railways (11 370)*
a) Cost of track materials	700 000 *(107.1)*
b) Railway Staff wages	5 200 000 *(796.1)*
c) Contractors	500 000 *(76.6)*
d) Total costs *(a + b + c)*	6 400 000 *(379.8)*

M. WEISSENBRUCH & Co. Ltd.
Printer to the King
(Manag. Dir.: P. de Weissenbruch,
238, chaussée de Vleurgat, XL)

Edit. responsible : P. Ghilain

PRINTED IN BELGIUM